NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

THESIS

BUSINESS PROCESS REENGINEERING IN THE INVENTORY MANAGEMENT TO IMPROVE AIRCRAFT MAINTENANCE OPERATIONS IN THE INDONESIAN AIR FORCE

by

Martinus Bram Susanto

June 2006

Thesis Advisors: Glenn R. Cook
Uday Apte

Approved for public release; distribution is unlimited

THIS PAGE INTENTIONALLY LEFT BLANK

REPORT DOCUMENTATION PAGE			*Form Approved OMB No. 0704-0188*

Public reporting burden for this collection of information is estimated to average 1 hour per response, including the time for reviewing instruction, searching existing data sources, gathering and maintaining the data needed, and completing and reviewing the collection of information. Send comments regarding this burden estimate or any other aspect of this collection of information, including suggestions for reducing this burden, to Washington headquarters Services, Directorate for Information Operations and Reports, 1215 Jefferson Davis Highway, Suite 1204, Arlington, VA 22202-4302, and to the Office of Management and Budget, Paperwork Reduction Project (0704-0188) Washington DC 20503.

1. AGENCY USE ONLY *(Leave blank)*	**2. REPORT DATE** June 2006	**3. REPORT TYPE AND DATES COVERED** Master's Thesis

4. TITLE AND SUBTITLE: Business Process Reengineering in the Inventory Management to Improve Aircraft Maintenance Operations in the Indonesian Air Force.	**5. FUNDING NUMBERS**
6. AUTHOR(S) Martinus Bram Susanto	
7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES) Naval Postgraduate School Monterey, CA 93943-5000	**8. PERFORMING ORGANIZATION REPORT NUMBER**
9. SPONSORING /MONITORING AGENCY NAME(S) AND ADDRESS(ES)	**10. SPONSORING/MONITORING AGENCY REPORT NUMBER**

11. SUPPLEMENTARY NOTES The views expressed in this thesis are those of the author and do not reflect the official policy or position of the Department of Defense or the U.S. Government.

12a. DISTRIBUTION / AVAILABILITY STATEMENT Approved for public release; distribution is unlimited	**12b. DISTRIBUTION CODE**

13. ABSTRACT (maximum 200 words)

The Indonesian Air Force has utilized computers in its administration as early as 1990. The computers, however, have not yet been optimized to support inventory management in aircraft maintenance operations, especially for the helicopter fleet. The processes for materials procurement to support the maintenance operations still rely heavily on the services of intermediaries'. Even though the Air Force has already adopted the Automatic Logistic Management System (ALMS), this has several weaknesses in supporting the material procurement processes.

The objective of this study is to propose the implementation of the Material Requirement Planning (MRP) method to improve inventory management in the Air Force's helicopter fleet. It is hoped that by implementing the MRP, the Air Force can get the right materials in the right amount at the right time without imposing unnecessary costs by minimizing the roles of the intermediaries.

The implementation of MRP, however, cannot be done without redesigning the business process in material acquisition and transforming it to an IT-enabled business process. Therefore, this study also discusses the Business Process Reengineering (BPR) concept in order to support the implementation of the MRP.

14. SUBJECT TERMS Inventory Management, Business Process Reengineering, Business Transformation, Material Requirement Planning, Information Technology, Supply Chain.	**15. NUMBER OF PAGES** 103
	16. PRICE CODE

17. SECURITY CLASSIFICATION OF REPORT	**18. SECURITY CLASSIFICATION OF THIS PAGE**	**19. SECURITY CLASSIFICATION OF ABSTRACT**	**20. LIMITATION OF ABSTRACT**
Unclassified	Unclassified	Unclassified	UL

NSN 7540-01-280-5500 Standard Form 298 (Rev. 2-89)
Prescribed by ANSI Std. 239-18

THIS PAGE INTENTIONALLY LEFT BLANK

Approved for public release; distribution is unlimited

BUSINESS PROCESS REENGINEERING IN THE INVENTORY MANAGEMENT TO IMPROVE AIRCRAFT MAINTENANCE OPERATIONS IN THE INDONESIAN AIR FORCE

Martinus Bram Susanto
Captain, Indonesian Air Force
B.S., Indonesian Air Force Academy, 1994

Submitted in partial fulfillment of the
requirements for the degree of

MASTER OF BUSINESS ADMINISTRATION

from the

NAVAL POSTGRADUATE SCHOOL
June 2006

Author: Martinus Bram Susanto

Approved by: Glenn R. Cook
Thesis Advisor

Uday M. Apte
Thesis Co-Advisor

Robert N. Beck
Dean, Graduate School of Business and Public Policy

THIS PAGE INTENTIONALLY LEFT BLANK

ABSTRACT

The Indonesian Air Force has utilized computers in its administration as early as 1990. The computers, however, have not yet been optimized to support inventory management in aircraft maintenance operations, especially for the helicopter fleet. The processes for materials procurement to support the maintenance operations still rely heavily on the services of intermediaries'. Even though the Air Force has already adopted the Automatic Logistic Management System (ALMS), this has several weaknesses in supporting the material procurement processes.

The objective of this study is to propose the implementation of the Material Requirement Planning (MRP) method to improve inventory management in the Air Force's helicopter fleet. It is hoped that by implementing the MRP, the Air Force can get the right materials in the right amount at the right time without imposing unnecessary costs by minimizing the roles of the intermediaries.

The implementation of MRP, however, cannot be done without redesigning the business process in material acquisition and transforming it to an IT-enabled business process. Therefore, this study also discusses the Business Process Reengineering (BPR) concept in order to support the implementation of the MRP.

THIS PAGE INTENTIONALLY LEFT BLANK

TABLE OF CONTENTS

LIST OF FIGURES

THIS PAGE INTENTIONALLY LEFT BLANK

LIST OF TABLES

THIS PAGE INTENTIONALLY LEFT BLANK

ACKNOWLEDGMENTS

I would like to appreciate the insights, patience and encouragement given by my advisors Professor Glenn R. Cook and Professor Uday M. Apte. I also acknowledge the support of my senior officers at the Air Force Headquarters as well as my co-workers at the Helicopter Maintenance Squadron of the Indonesian Air Force, who were ready and willing to support my research by providing data and answering my questions. Lastly I would like to thank my wife, Tety, and my daughter, Priska, for their understanding, patience, and support during this long process.

THIS PAGE INTENTIONALLY LEFT BLANK

I. INTRODUCTION

A. BACKGROUND

In the early years after the Netherlands acknowledged sovereignty of the Republic of Indonesia in 1949, most of the weapon systems in the military were inherited from the Koninklijke Netherlands Indische Lager (KNIL), the colonial army of the Dutch. The air force inherited, from the Koninklijke Luchtmacht (KL), a number of aircrafts including fighters and medium bombers as well as their spare parts and the logistics system and used them to fight the separatist movement throughout the state. Since the technology at that time was not as sophisticated as it is today, the ability to troubleshoot or deal with the supply scarcity was not very high. If any particular spare part could not be found in the warehouse, the mechanic just simply took it from another aircraft which was not operational (or cannibalized it) or made it in the shop. Some of the engine components of the P-51 fighters are similar to those automobile engines. During this period, all of the aircraft in the Indonesian Air Force were U.S. built aircraft.

When the political situation changed in the late 1950s, the main source of weapon systems for the Indonesian armed forces was shifted to the Eastern Block (Soviet Union and its allies). This change was the result of the foreign policy of President Soekarno towards the western countries. Even though Indonesia is a non block state, the policy of President Soekarno put Indonesia on the opposing side against the United States and, as a consequence, the United States suspended spare part support for the Indonesian Armed Forces' weapon systems, including those of the Air Force. Anticipating the situation, President Soekarno decided to purchase a large amount of weapon systems including aircraft, radar and ships from the Soviet Union and its allies to back up the weapon systems which existed.

After a political disaster in 1965, and subsequent military coup when President Soekarno was toppled by General Soeharto in 1968, the Soviet Union support for the Indonesian military was terminated. This led to the collapse of the once powerful air force in the South East Asia region. To overcome the situation, the new government preferred the non-communist states as the main providers for the military. The first

weapon system arrived in the form of UH-34D helicopters from the United States in the early 1970s. This was followed by various weapon systems and other military equipment for the navy as well as the army. From then on, the mainstay of the weapon systems came from various western countries.

Along with the new weapon systems, a new purchasing method was required. In the previous method, the military equipment was purchased using communication between the Indonesian government and the government of the supplier state, commonly known as G-to-G. The new method was different. It relied heavily on intermediary services. Each department of the armed forces had its own intermediaries or service providers. The Air Force's transport aircraft department might have different intermediaries from the helicopter department. The Helicopter Subdirectory at the Aeronautic Directorate of the Logistic Department, Air Force Headquarters, for example, upon receiving the request for spare parts from the user units held a tender to select the provider. Then, the winner needed approval from the Chief of Staff of the Air Force. After the approval was granted the provider (intermediary) could start the purchasing process. When the materials arrived, they went to the Material Department to be put in the inventory record before distribution. If there were some new material – usually with a new part number – the department would hold the materials longer to allow for data processing. This made the supply system lengthy, inefficient, and in many cases, quite costly.

The problem with this method was that the spare parts were often delayed for several months or even years. Because of the lengthy process and lobbying between the intermediaries and the higher command, sometimes the material purchased was not in the appropriate numbers or arrived too late or even not the material ordered – different type or part number. This affected the combat readiness significantly. There was, however, an effort to reduce the problem. The Air Force installed and operated a logistic management system called ALMS (Automatic Logistic Management System).

The ALMS was introduced to back up the F-16 fighters purchased in the late 1980s. It was intended to cut some processes and directly link the users (weapon systems unit or operator) to the manufacturer. The system utilized a computer (only the monitors,

keyboards and printers) connected by satellite signal to the CPU which was located at Halim Perdanakusumah Air Force Base in Jakarta. With this system, if the operator in the field required some spare parts or needed to make an aircraft status report, the data was inputted and automatically transmitted to the higher command, support command, logistic command and the aircraft manufacturer. Therefore, by using this system, it was expected that the operator in the field could get the right material at the right time. Figure 1 illustrated the ALMS' information flows between each unit in Indonesia and the factories in the USA.

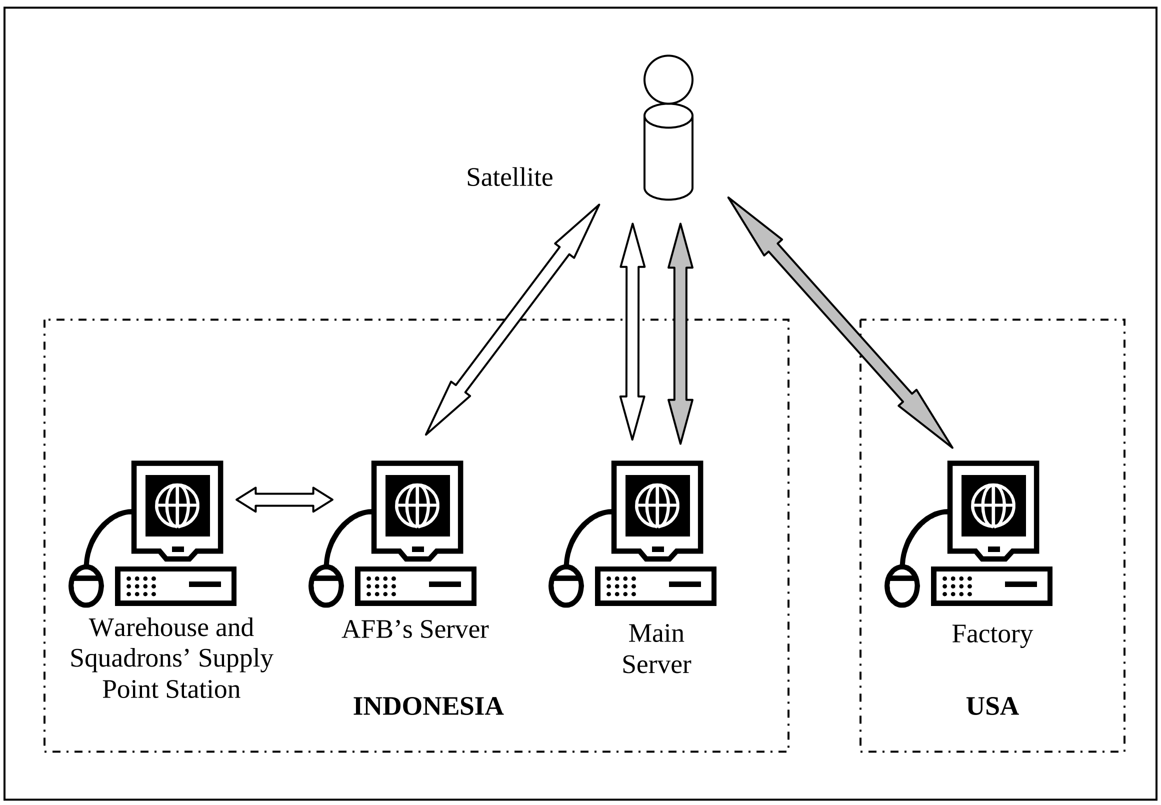

Figure 1. ALMS Network Diagram.

However, there were three problems with the ALMS. First, the system was complex and quite expensive to operate. It used a different type of hardware from the PC commonly used in the offices. The spare parts for the system (IBM built) were not

available in the local market. For example, the monitors used were still the old RGB types which are very rare (the model was already obsolete for the home PC users) in the market now and the keyboard type had more keys on it and had to be imported from the United States. The system at one air force base was connected to other air force bases or command using a satellite from which the data were transmitted and retrieved by a large disk shaped antenna. The spare parts for the antenna had to be imported. Therefore, it was difficult to maintain, especially when the system was installed in a thunderstorm rich region. The helicopter squadrons and the helicopter maintenance squadron are based in the region which is number two in terms of thunderstorm frequency. The antenna disk of the ALMS has been struck at least 3 times a year by lightning since it was installed.[1]

The second problem was that the ALMS was acquired by using the FMS (Foreign Military Sales). Therefore, it was also closely connected with the political situation between Indonesia and the United States. When political issues strained the relationship between them, the ALMS was also affected. For example, when the US declared an embargo of military related material to Indonesia, the ALMS was rendered inoperative since the system was disconnected. In short, the ALMS was not an independent system.

The third problem was that the system was not compatible with some of the aircraft in the Indonesian Air Force inventory. The Air Force had also purchased some aircraft and helicopters, including their weapons, from Europe. These aircraft were not integrated into the ALMS. In the past, the Air Force tried to include the European built aircraft in the system, but the information flow stopped at the Material Department, and did not continue to the aircraft manufacturer. Even some U.S. built aircraft were not integrated with the ALMS, especially the old ones such as the UH-34T helicopters.

Based on the above circumstances, the Air Force needs more appropriate inventory management and an information system to support it; one which will not depend only on one source and will be compatible with all aircraft in its inventory. The combination of Inventory Management and Business Process Reengineering concepts should be a better solution.

[1] This is based on the author's experience when stationed in Atang Sendjaja AFB from 1995 to 2004.

B. OBJECTIVES

The objectives of this thesis are to discuss the theories of Supply Management, including Inventory Management and Process Improvement, and recommend a model for the Indonesian Air Force to improve supply management to support the aircraft maintenance operation. In addition, this research will address the possible implementation of an information system in conjunction with a supply management system. Recommendations from this research will include why supply management supported by an information system is important for aircraft maintenance operation and how this model might be implemented in the Indonesian Air Force. This research will provide a conclusion and recommendation for the implementation of supply management in the aircraft maintenance operation.

C. RESEARCH QUESTIONS

The research questions that will be analyzed and discussed in this thesis are as follows:

- How to improve the inventory management in the Indonesian Air Force's aircraft maintenance operation and support it by using the appropriate information system.
- How to improve the supply management in the aircraft maintenance process in order to reduce time and unnecessary costs.
- What might affect the implementation of the information system in the aircraft maintenance operation and management.
- How effective the previous information system used by the Indonesian Air Force in its aircraft maintenance management was and how it was implemented.

D. SCOPE AND LIMITATION

This research will cover an overview of business process engineering (BPR) and operation management. The focus will be on the basic process of BPR, inventory management and improvement of the process of business operation management to appropriately provide a basic model for the Indonesian Air Force in conducting the

aircraft maintenance operations. The scope of aircraft maintenance in this research is limited to helicopter maintenance operations.

The research will be based solely on the literature reviews; therefore, it will not address any detailed application of the information technology in the BPR. It will not discuss the hardware configuration nor the software required. It will simply provide the basis for further action into the potential creation of the aircraft maintenance management network as the information system in the Indonesian Air Force is still in the development phase.

E. RESEARCH METHODOLOGY

The methodology used in this thesis research consists of conducting a literature review of Business Process Reengineering, E-Business and Inventory Management theories and guidelines, use of library information resources, including the GAO reports on U.S. DoD performance following business process transformation, and examines various websites. The initial phase was started by performing a literature review of business process reengineering and inventory management. This was followed by examining the conditions in the Indonesian Air Force maintenance operations at various levels, from the unit maintenance level through the depot maintenance level, as well as the current information system.

After deriving lessons from the reviews, the focus shifted to the factors that might improve the aircraft maintenance performance by examining the possibility of utilizing information technology and the possible ways of building a network using resources available in Indonesia.

F. ORGANIZATION OF STUDY

The study is organized into six chapters. Chapter I will consist of an outline of the research background, the objectives of the study, the research questions, scope and limitation and methodology of the study.

Chapter II will provide an overview of the aircraft maintenance systems in the Indonesian Air Force's helicopter squadron. This will include the aircraft maintenance cycle at the unit maintenance level as well as at the medium and depot maintenance level. It will also provide an overview of the Indonesian Air Force's current supply chain management.

Chapter III will discuss the operation management aspects of inventory management and process improvement, including Economic Order Quantity, Material Requirement Planning and Just-In-Time concept.

Chapter IV will discuss Business Process Reengineering and Business Transformation. This will include an overview of the implementation of information technology to support the flow of information in business process transformation.

Chapter V will discuss an integration model of the operation management aspect and the e-business concepts for business transformation in the Indonesian Air Force's maintenance operation. It will also discuss the current information system used by the Indonesian Air Force.

Chapter VI will provide the conclusion of the research concerning Business Process Reengineering in the aircraft maintenance operation and recommendations for further study.

THIS PAGE INTENTIONALLY LEFT BLANK

II. AIRCRAFT MAINTENANCE SYSTEM

A. OVERVIEW

Aircraft maintenance in the Indonesian Air Force is performed by three different major commands. The first two are the Air Force Operation Commands (KOOPSAUs); each commanded by a two-star general. The First Air Force Operation Command (KOOPSAU I) is responsible for the Air Force operation in the western part of the Indonesian archipelago. The Headquarters of the KOOPSAU I are located in Jakarta. The Second Air Force Operation Command (KOOPSAU II) is responsible for the Air Force's operation in the eastern part of the Indonesian archipelago. The Headquarters of the KOOPSAU II are located in Makassar (the city's name was changed from Ujungpandang).

The Air Force's helicopter squadrons are based in an Air Force Base within the KOOPSAU I territory, even though some helicopters are deployed in the KOOPSAU II area. Therefore, the helicopter squadrons are considered as part of the KOOPSAU I inventory, even though they often operated in both KOOPSAU simultaneously, depending on the mission. The helicopter squadrons' maintenance section provides daily maintenance, as well as periodic maintenance. Besides the helicopter squadrons, there is a helicopter maintenance squadron under the command of the same Air Force Base. Its main mission is to provide medium level maintenance for the helicopters to support the units' mission. Based on this arrangement, the maintenance performed by the helicopter squadrons and the helicopter maintenance squadron is under the responsibility of the KOOPSAU I. Figure 2 illustrates the area of responsibility boundary between KOOPSAU I and KOOPSAU II.

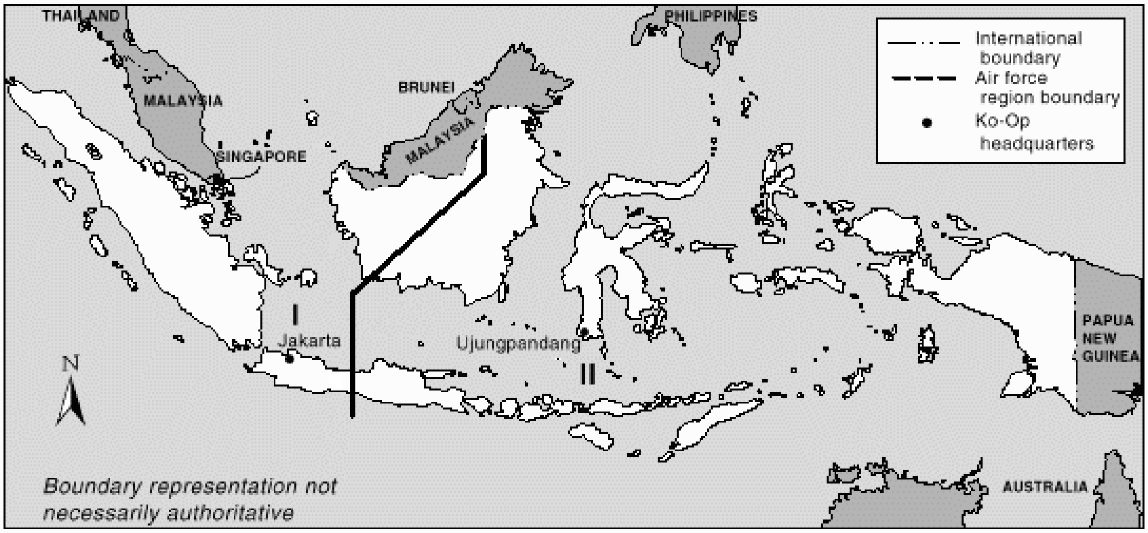

Figure 2. KOOPSAUs' Area of Responsibility.

The third major command which provides aircraft maintenance is the Air Force Material Maintenance Command (KOHARMATAU). This command, also headed by a two-star general, is the maintenance center for the entire weapons system and other equipment including ground vehicles and machinery in the Air Force inventory. Several Maintenance Depots are served under this command. One of them, the 10th Aircraft Maintenance Depot (DEPOHAR 10) has a helicopter maintenance unit: the 16th Maintenance Unit or SATHAR 16. The SATHAR 16 is responsible for performing the highest maintenance level for all Indonesian Air Force helicopters. The unit is responsible for major overhauls or major repairs to the helicopter airframes. This unit works in conjunction with the other units within the DEPOHAR 10, such as SATHAR 13 for engine's *deep inspection*[2] and other in-depth inspection procedures and SATHAR 12 for component fabricating. In addition to the aircraft maintenance depots under the Air Force Material Command, there are two electronic maintenance depots (DEPOHAR 21 and 22) which take care of the maintenance of the aircraft avionics and other electronic equipment such as communication devices.

2 This is a special inspection on engine's centrifugal compressors using ultrasonic or x-ray methods.

B. THE AIRCRAFT MAINTENANCE CYCLE

In general, the aircraft maintenance system in the Indonesian Air Force is not different from that of other countries except for the terminologies they use. Maintenance is divided into three stages: the unit level maintenance (light maintenance), the intermediate level maintenance (medium maintenance) and the depot level maintenance (major maintenance). Unit level maintenance cycles are performed at the helicopter squadrons by the squadron's maintenance personnel, either at the home base or at the duty station, which may be far from the home base. The intermediate level maintenance is performed at the Maintenance Squadron. However, there is some degree of flexibility. If the aircraft is off of the base, far from its duty station, then the maintenance squadron will assign one team to perform the maintenance on site. On the other hand, the depot level maintenance has no such flexibility. The maintenance has to be carried out at the 10th Aircraft Maintenance Depot (DEPOHAR 10). If the aircraft is at its duty station and cannot be flown to the maintenance depot, then the DEPOHAR 10 will assign one team to dismantle the aircraft and bring it home using a C-130 aircraft.

1. Unit Level Maintenance

Unit level maintenance is divided into three basic cycles. The lightest cycle is the periodic 25-hour maintenance operation or commonly named PO 25 – periodic overhaul every 25 hours which means the maintenance operation is performed on the aircraft every 25 flight hours. The work performed during this 25-hour cycle is mainly re-greasing the moving parts, filter cleaning and oil level checks. This maintenance type is applied to both SA-330 Puma and AS-332 Super Puma helicopters and can be completes in less than one day.

The next cycle is the 50-hour maintenance operation. Basically, the operation is the same as the 25-hour, except for some additional tasks, especially on the avionic equipment. The maintenance operation, known as PO 50, can usually be completed within one day, as well. After PO 50, the aircraft will undergo the PO 25 again before the next maintenance phase.

The third phase is the biggest maintenance operation for the unit. It is called PO 100 since it must be undergone every 100 flying hours. More work is performed during this phase. The Main Rotor Gearbox lubricating oil is changed, torque inspection, and re-torquing if necessary are carried out on the tail boom section, and inspection of the Engine Drive Coupling are some procedures. This heaviest part[3] of the light maintenance cycle usually can be done within two days, if there is no defect in the components inspected. On that second day, the aircraft is ready for test flight.

2. Intermediate Level Maintenance

The helicopters periodically undergo intermediate level maintenance called P2. There is a difference between the SA-330 Puma helicopter and the AS-332 Super Puma helicopter pertaining to the intermediate level maintenance or the P2. The SA-330 undergoes medium level maintenance every 400 flying hours while the P2 for the AS-332 is every 500 flying hours and then every 1000 flying hours. The difference between the 500 hour maintenance and the 1000 hour maintenance for the Super Puma is related to periodic engine maintenance.

The engine of the SA-330 Puma has an extra maintenance step which is a problem for maintenance scheduling. As a result of several engine failures, caused by centrifugal compressor damages, the engine must undergo an additional maintenance called "deep engine inspection." The compressor must be inspected every 250 flying hours. On the fourth inspection, the centrifugal compressor must be removed for ultrasonic inspection. If there is a crack found on one or more turbine blades, then the compressor must be replaced. This type of maintenance is not included in the periodic aircraft maintenance, but considered and reported as special maintenance.

The medium level maintenance, for both helicopter types, can be done within two weeks under normal conditions, meaning there is no major defect found during the inspection. The biggest challenges during this maintenance level are the rotor vibration

[3] The heaviest part of this maintenance is the removal of both engines' exhaust pipes to inspect the engine drive shaft and the Horizontal Drive Shaft which connect the main rotor gearbox and the intermediate gearbox.

(either the main rotor or tail rotor or sometimes both), and the engine power rating check. These two problems require most of the maintenance time.

3. Depot Level Maintenance

Depot level maintenance is performed when the aircraft reaches 6000 flying hours. This type of maintenance is also known as P4 or major inspection. Both SA-330 Puma and AS-332 Super Puma have the same maintenance period for this maintenance level: every 6000 flying hours or 180 months, whichever comes first.

During this maintenance, which is also known as the heavy maintenance, the entire aircraft's components are dismantled prior to the *Inspection and Repaired as Necessary* (IRAN). More deep inspections are performed including x-ray and ultrasonic inspection of the airframe. All the avionics and electric equipment are brought to the Avionic Electronic and Instrument (AEI) shop. The aircraft are also re-weighed, re-balanced and finally repainted before undergoing a flight test. The overall time required to finish this depot level maintenance is six months under normal conditions.

In addition to this major periodical inspection, depot level maintenance also includes one special inspection called "Aging Inspection." This type of inspection is intended to "extend the life" of a helicopter which should undergo major inspection (P4) but reaches neither its calendar life nor the flying hours required due to its inactivity. When a helicopter reaches the calendar time of 162 months, since it was new or since the previous major inspection, it must undergo the Aging Inspection which can ideally be done within two months. The maintenance will put the helicopter into operational status until it reaches 180 months of calendar time or 6000 flying hours.

When a helicopter has been involved in an incident or accident[4] and has been seriously damaged, the aircraft has to go to the maintenance depot for major repairs or even to be rebuilt. The aircraft maintenance depot rebuilt one medium transport helicopter which had not been serviceable for years – it was an SA-330 helicopter – and made it the most reliable aircraft in the helicopter fleet.

[4] Indonesian Air Force uses incident terminology to describe a mishap which is not cause a total loss of the aircraft. The "accident" term is used to describe the mishap with total aircraft loss.

C. UNSCHEDULED MAINTENANCE

Unscheduled maintenance can be carried out by all maintenance levels, from the helicopter squadron to the maintenance depot. Unscheduled maintenance is defined as every maintenance operation which is not included in the periodic maintenance described previously. This maintenance is reported as special maintenance. Unscheduled maintenance covers all aircraft's main component replacement and troubleshooting.

The most common type of unscheduled maintenance is defect troubleshooting, either minor or major. Minor defect troubleshooting covers light bulb replacement up to repairing the intercom system. Major defect troubleshooting covers an engine anomaly assessment, landing gear malfunction up to main rotor vibration. If the aircraft has been involved in a minor accident and requires repair, this is also categorized as unscheduled maintenance.

If the maintenance personnel can not solve the problem because of limited tools and equipment, then the aircraft is sent to the helicopter maintenance squadron. When the helicopter maintenance squadron cannot solve the problem either, the aircraft is sent to the DEPOHAR 10.

In the Helicopter Maintenance Squadron, the term unscheduled maintenance is also used for aircraft component repair including the engines. The maintenance squadron is authorized to perform limited repair on some of the main rotors as well as the engine parts.

D. CURRENT SUPPLY MANAGEMENT

The materials required to undergo the maintenance operation as described flow through two separate distribution channels. The first channel is in the maintenance corps domain. It starts from the field units including the helicopter squadrons and the helicopter maintenance squadron. Based on the maintenance program and the flying hours allocated by the higher command for a year, the maintenance officers compile a list containing the spare parts required, the main components, and also the consumable materials such as POL (petroleum, oil, and lubricant) and cleaning equipments. When

the materials on the list are not available in the warehouse, a material request is sent to the higher level of authority.

The information forms, containing the material requested, go from the unit performing the maintenance to the Department of Logistics which will send it to the 1st Air Force Operation Command (KOOPSAU I). The maintenance units at the depot level also follow the same pattern but the materials request forms go to the Air Force Material Command. Both commands will forward the request to Air Force Headquarters. The unit responsible for handling this request is the Helicopter Subdirectory at the Aeronautic Directorate, Air Force Headquarters (SUBDISPESHELI DISAEROAU). At the Helicopter Subdirectory, all of the materials requested are sorted based on priority and the availability of funds. When the sorting process concludes, the list is sent to the intermediaries who, in turn, will purchase the items from the market. They will follow their own procurement procedures.

The second supply channel is within the supply corps domain. After the ordered materials arrive, they will go to the Materials Directorate. The directorate will assign some of its personnel to hold an inspection of the materials before they are distributed to the unit through various warehouse levels. The materials are ready to be used by the user units (helicopter squadrons and helicopter maintenance squadron) after they arrive at the Air Force Base Warehouse (GPL).

The data of the inventory in the warehouses are updated annually. The inventory list is intended to help the maintenance officers in the helicopter squadrons to plan for materials required for maintenance operations for a certain period. From the list, the officers can see the total number of items available in the warehouse and compare it with their needs according to the maintenance plan worksheet. If there seems to be a shortage on some items, the maintenance officers will begin the material request sequence to the higher command level. The material acquisition flowchart for the maintenance operation at all three levels is described in Figure 3.

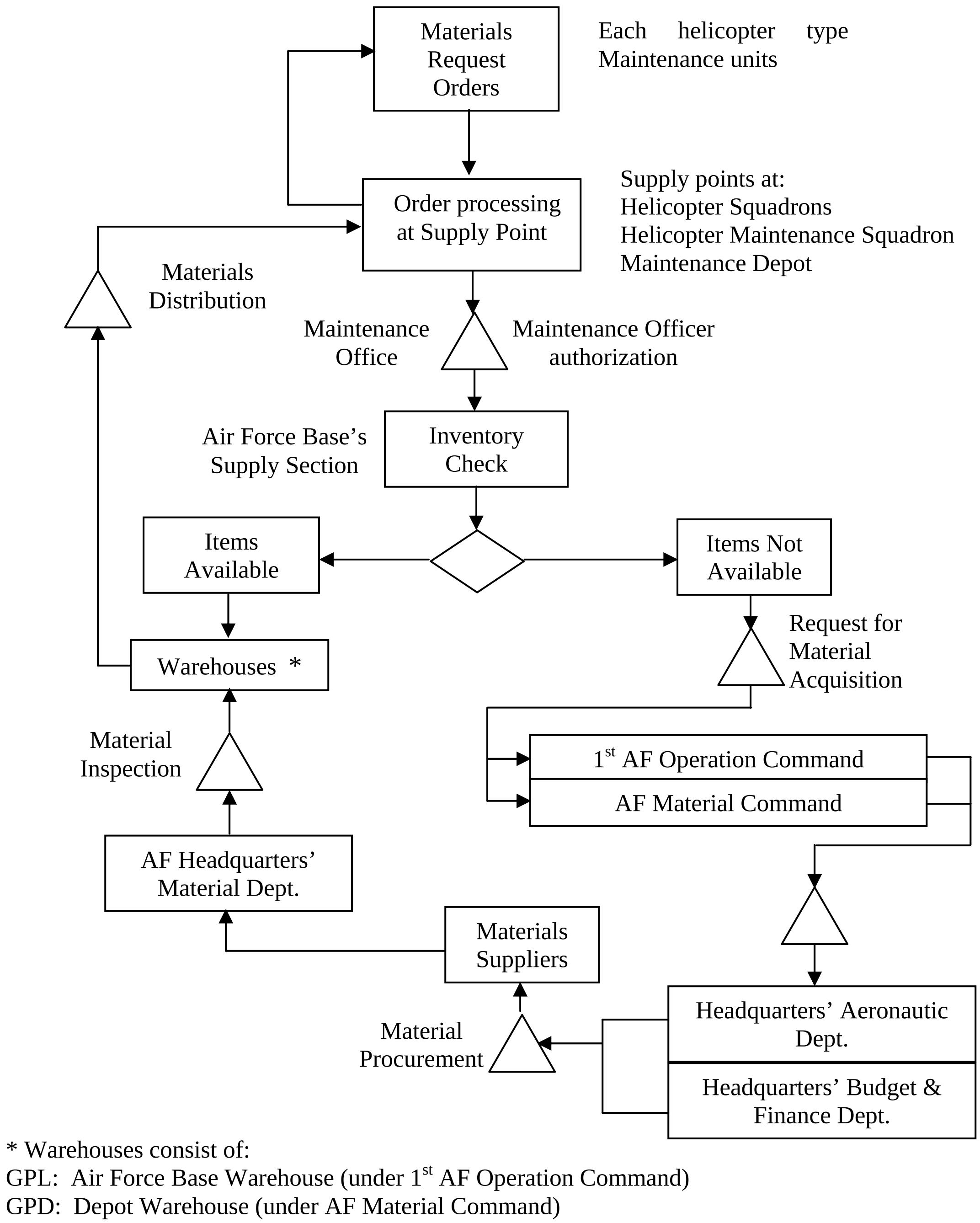

Figure 3. Material Acquisition Flowchart.

Since the whole supply process is run on a paper-based system, some problems are encountered. First, the data pertaining to the inventory in the warehouse is not in real time. The inventory in the warehouse is checked manually and the number of items

available on the racks or shelves is recorded in several item list books before it is transferred to the computer. The input process is also done manually, which means that the input is manually fed to the computer using simple word processing software. After the complete data are entered, the item list is printed. The printed lists, bound as a book, are used as a reference for the maintenance officers in those squadrons as well as the logistic officers to determine decisions regarding the item's availability. The annual updating process requires at least two weeks to accomplish. Then, it requires several more days to transfer the data from the temporary books to the inventory cards and to the computer, before the list is printed and compiled as the warehouse's inventory. In the meantime, when the users (helicopter squadrons or maintenance squadron) need some materials for their maintenance operations during an inventory check, the items are drawn from the racks or shelves and recorded in a temporary record before the status of a particular item or items in the computer, is updated. Thus, the data in the "official" inventory books issued by the warehouse sometimes do not reflect the actual availability of materials.

The second problem is time. When the helicopter squadrons or the maintenance squadron require a particular item for the maintenance operation, the mechanic goes to the supply point and writes down the name of the item as well as the part number, and the quantity he or she requires. The supply personnel then copy the request to their request record books and fill out the material request form, which must be signed by the authorized officers, both the maintenance officer and supply officer. Then, the supply personnel go to the warehouse and place the order. The warehouse personnel process the order and check the item's availability from the inventory cards. If it is found, the request is recorded in a warehouse record book as well as on the appropriate inventory card before the item is handed over to the supply point personnel who will bring the item back to the unit. The overall process for one order usually takes 40 minutes to one hour. Because of this time constraint, usually the supply point officer holds the full request order until it reaches several items so the supply personnel can use their time effectively.

Third, there is always a risk of duplication of the material request. The problem arises when the inventory list books are distributed to the helicopter and maintenance squadrons. In several cases, maintenance officers note the spare part required for a

certain maintenance operation solely based on a particular maintenance type and are not aware that the other maintenance types also require the same items. For example, a 50 hour periodical maintenance (PO 50) requires item “A” in as many as five pieces. If the squadron planned to perform five PO 50s for the month, the total amount of item “A” required for this maintenance type would be twenty five pieces. The inventory list says thirty pieces are available at the warehouse. It seems the quantity of item “A” is sufficient to support the maintenance. The PO 50 will leave five pieces at the warehouse. The squadron’s next plan for the month is to perform two 100-hour periodical maintenances which required the same item “A” in as many as ten pieces for each time, which means the quantity required is twenty. Based on the item list, there are thirty pieces of item “A” at the warehouse; therefore ten pieces will be left and there will be no problem. There is, however, a serious problem. When the two maintenance operations spare parts requirement lists are compiled, actually the squadron may be short of item “A” as many as five items (total quantity required for both maintenance subtracted by the total quantity available in the warehouse). This “incident” can be worse if other squadrons require the same item for their maintenance operation and are not aware about the real situation which may then affect the logistical plan. The usual way to overcome the problem is to look for the items required from other warehouses or request the materials from the higher command.

In several special cases, rather than waiting for the material which is still in the procurement process, the Air Force transfers the materials from one unit to another. If the material is badly needed by a user unit, it will be transferred directly to that unit and then the paperwork will follow a few days later. The same procedure occurs in a reverse flow, if the DEPOHAR 10 needs some component not available at its warehouse, but available at the helicopter base warehouse. The material transfer between two different warehouses from two different Air Force bases (GPL to GPD or vice versa) requires the authorization from the higher command.

In case of emergency, the materials required for the helicopter immediately needed for a certain mission also can be purchased from the local aircraft company which operates the same helicopter type, or from the only Indonesian aircraft manufacturing company, the Dirgantara Indonesia Aircraft Industry (PT.D.I.). The last option depends

on the inventory availability since the PT.D.I. itself depends on the materials procured from European aircraft manufacturing companies such as the Eurocopter or the American Bell Boeing.

E. CHAPTER SUMMARY

The Indonesian Air Force is still using an old fashioned paper based supply management system to support its aircraft maintenance operations even though the utilization of the computer is already widespread throughout the service. The computer is widely used primarily as a typewriter with a monitor attached regardless of the fact that the information era that could support supply management emerged several years ago along with new supply management techniques. This circumstance often hinders the maintenance operation management efforts and causes unnecessary delays in the process especially in the material acquisition process required by the maintenance operation.

Several problems that can be identified from these weaknesses are as follows:

- The inventory status records from the warehouses are not real-time.
- The information flow pertaining to material acquisitions processes requires a lot of time which leads to inefficiency.
- There is always a risk of duplication on certain materials requests which are used by more than one unit.
- It requires a lot of effort to track the movement of material between warehouses and units.
- Materials are not ordered in exact requirement.

Chapter Three will discuss several inventory management concepts as a methodology to improve the Indonesian Air Force's inventory system. This research is limited to the helicopter fleet, and may be appropriate for future aircraft maintenance in the Indonesian Air Force.

THIS PAGE INTENTIONALLY LEFT BLANK

III. INVENTORY MANAGEMENT

A. INTRODUCTION

Inventory management enables an organization to use resources efficiently to meet customers' demands. Neale et al (2003) argue that "effective supply chain inventory management can be crucial for corporate success." In the production process, the company adds value to the goods (input) from the suppliers before they reach the customers (Harrison, 2003). The term of suppliers can be an upstream process within the organization or external vendors. On the other hand, the customers of the finished products or service can also be the final customers (buyers) or a downstream operation that uses the output of a process as an input for another process.

Harrison (2003) says that three types of flows occur in the supply chain: product, information, and funds. Inventory management manages these three types of flows. Figure 4 illustrates the three types of flow between the customer or user and the supplier. The product flows from suppliers to the user, the funds flow from the user to suppliers and the information flows in both directions. Coordinating those three flows effectively is the goal of inventory management. When this goal is reached, the overall goal for the company, which is to maximize profit and return on investments, can also be reached.

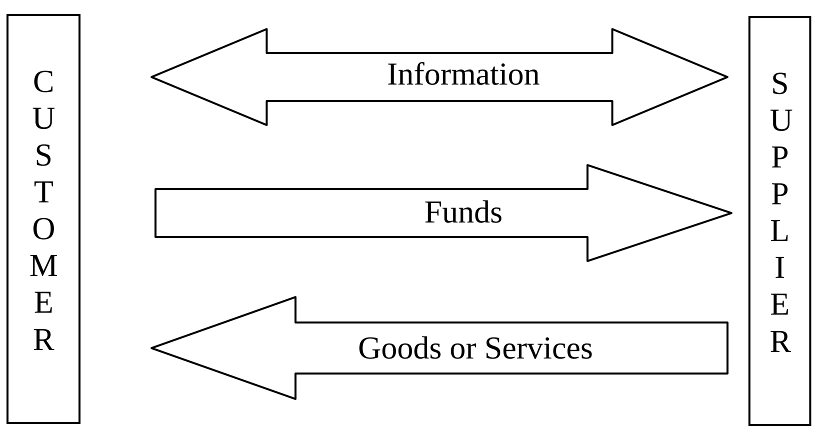

Figure 4. Three Types of Flows between Customer and Supplier.

Inventory management is deeply concerned with the right time to make an order in conjunction with its impacts on costs and services. The main purpose of the inventory management activities is to determine a series of decisions pertaining to the material acquisition process. It includes the decision to determine how often to replenish the inventory (order frequency) and how large is the replenishing size (order quantity) while at the same time avoiding supply shortage and reducing holding costs.

Supply shortage occurs when the inventory level becomes so low that it can not support customers' demand. This is a serious situation when helicopter squadrons and the helicopter maintenance squadron cannot get supplies in sufficient quantities to support the Air Force's missions. There are several cases when the helicopters could not perform the mission given by the higher command because spare parts or components were not available. On the other hand, there were several cases when the Air Force had to spend money unnecessarily to cover the holding costs.[5] While the Air Force inventory is free from taxes and relatively safe from theft, most of the holding cost is spent to cover breakage as well as obsolescence. Obsolescence occurs when the materials have reached their product life before they are used in the system. It also occurs when the aircraft manufacturer changes the part number of a certain part, leading to different material specifications.

The costs of making rush orders to cover supply shortage and expired materials was the result of the forecasting methods currently used. The Air Force's Helicopter Subdirectory procured the materials using the long-term forecasting (yearly forecasting) method based on the flying hour allocation. To procure materials using only the forecast method, however, is not a good option. Simchi-Levi (2003) in his article "Tactical Planning for Reinventing the Supply Chain" explains the three principles of forecasts and their impact on the supply chain. Those principles are as follows:

- The forecast is always wrong.
- The longer the forecast horizon, the worse the forecast.

[5] The holding costs include the costs for the storage facilities, handling, insurance, obsolescence, depreciation, and the opportunity cost of capital. (Chase et al, 2001)

- Aggregate forecasts are more accurate.

Simchi-Levi explains that it is difficult to match supply and demand solely based on forecast. Moreover, he argues in the second principle that forecasting for a longer term is more difficult. Therefore, the common practice of employing only the forecast method is not recommended.

This chapter discusses the literature review of the following Inventory Management concepts: Section B describes the Economic Order Quantity. Section C describes the Material Requirement Planning. Section D discusses the inventory system of the Just-In-Time model that might be appropriate for Indonesian Air Force logistics system to provide the material required for the maintenance operations at the right time. A summary is provided at the end of the chapter in Section D.

B. ECONOMIC ORDER QUANTITY

The Economic Order Quantity (EOQ) model, as one of the two multiperiod inventory replenishment systems, is used to determine the order quantity for a certain period for the items for which the demands are independent.[6] This classic model has been widely known and adopted in the business world to manage product and inventory before Just-in-Time (JIT), Total Quality Management (TQM) and Material Requirement Planning (MRP) became popular. The model at that time was unnamed. As early as 1930s, the model was known as *Minimum Cost Quantity* (Piasecki, 2001). EOQ model is still widely used even though the current business trend is starting to use the MRP system model. The MRP, however, is still utilizing the EOQ forecasting to backup its *master production scheduling* for the item with independent demand. This basic EOQ model is used with assumptions that:

- The demand rate is constant.
- The lead-time for the order process is constant.
- Materials are ordered in lot sizes.

[6] The other model is the fixed-time period where the material is ordered based on the fixed order interval system. The demand for an item is independent if it is influenced by the market conditions and beyond the control of the operations. (Chase et al, 2001)

- Cost per order is fixed regardless of the order quantity.
- No shortage is allowed; the items ordered should arrive at the warehouses before the level reaches zero (stockout).

There are some factors that might influence the decision to choose this method. These factors are:

- It is not necessary to review and make an order to replenish the inventory periodically. As long as the inventory level is above the reorder point, there is no need to make any additional order.
- There is a chance to order additional numbers of the more expensive items since the average inventory level is low. The funds which are usually spared to purchase a large number of a certain item in order to avoid the stockout during the review period can be transferred to purchase the other items.
- This model is important to maintain the items critical for the aircraft maintenance since it is monitored closely through the continuous recording. With the close monitoring, there will be a quicker response to prevent the inventory stockout.

When using the EOQ model the inventory level has to be recorded continually. Every time an item is withdrawn from the warehouse or replenished, the record must be updated in order to keep track of the reorder point. The EOQ model will start the material order processes when inventory level at the warehouses reaches the reorder point. The idea is to set the reorder point so that "fresh" material from suppliers arrives when stock level reaches zero. An order will not be placed if the inventory level has not reach the reorder point, therefore it can reduce the cost of unnecessarily purchasing additional amounts of an item.

The first step is to determine the quantity of the item that will be ordered each time, Q[7]. To determine the quantity of the item, not only the ordering cost but also the holding cost should be put into consideration. The goal is to minimize the ordering and holding costs. Consequently, at the reorder size Q cost should be a minimum.

[7] This quantity is often also called the *batch* or *lot size*. (Beasley, 2001)

The basic equation for this model to determine the optimal Q is as follows:

Annual Carrying Cost = Annual Holding Cost (h) x Average Inventory (Q/2)
= hQ/2

Annual Order Cost = Cost per Order (A) x Orders per Year (D/Q)
= AD/Q
where D is demand rate (units per year)

The total annual cost for the inventory (TC) is the annual ordering cost plus the annual inventory carrying cost. Therefore the equation for TC is as follows:

$$TC = hQ/2 + AD/Q$$

Using calculus, the optimum order quantity that minimizes the total annual cost can be derived as follows:

$$\frac{d(TC)}{dQ} = -\frac{AD}{Q2} + \frac{hQ}{2} = 0$$

$$AD/Q^2 = h/2$$

$$Q^2 = \frac{2AD}{h}$$

$$Q = \sqrt{\frac{2AD}{h}}$$

The next step in using the EOQ model is to determine the reorder point, R. This is the point where an order will be placed and specified as a number of units. The reorder point is set such that the inventory on-hand can still be used to meet the demand rate D during the lead time, L. Lead time is a period when the materials supplier receives the order until the materials are received by the Indonesian Air Force, hence customer.

This basic model assumes the demand rate and the lead time are constant. Therefore the reorder point R is determined by the lead time of the demand rate. The equation is as follows:

$$R = L \times D$$

where L : the lead time for supplier

D : the demand rate

For example, the Air Force requires purchasing several Anti-dust rings to repair Main Rotor Head Spindle Sleeve components for one year.[8] The data for the anti-dust ring is given as follows:

Demand per year (D)	=	12 units/year
Cost per order (A)	=	$ 20
Holding cost per unit/year (h)	=	$ 13
Lead time (L)	=	6 months or 0.5 year

$$Q = \sqrt{\frac{(2)(20)(12)}{13}}$$

$$Q = 6.07 \rightarrow Q = 6$$

Since the result is 6.07 therefore the optimum number per order is rounded to six (Q = 6). Then, the next phase is to determine how many orders should be made each year. The calculation is shown as follows:

Number of order per year (N) = D/Q

= 12 / 6

N = 2 orders

The result shows that each year there should be two orders of six *anti-dust rings*. From the optimum quantity Q and the demand per year D we can calculate inventory cycle time as follows:

Inventory Cycle Time (T) = 1 / N

= 1 / 2 year = 6 months

8 Examples used here are only imaginary, since the exact numbers (especially the cost) cannot be determine since the data collected are different from every source.

The reorder point *R*, given that the lead time *L* is constant, is calculated as follows:

Reorder point (R) = D x L

= 12 x 0.5

= 6 units

From the calculations above, an order for *anti-dust rings* must be made when the inventory reaches 6 units in the warehouse. The quantity of anti-dust rings ordered is 6 units and the order is made twice a year.

Figure 5 illustrates the inventory replenishing process using the basic EOQ model. When the Q reaches the R, then the order is made and when the Q reaches 0, the replenishing materials arrive from the suppliers.

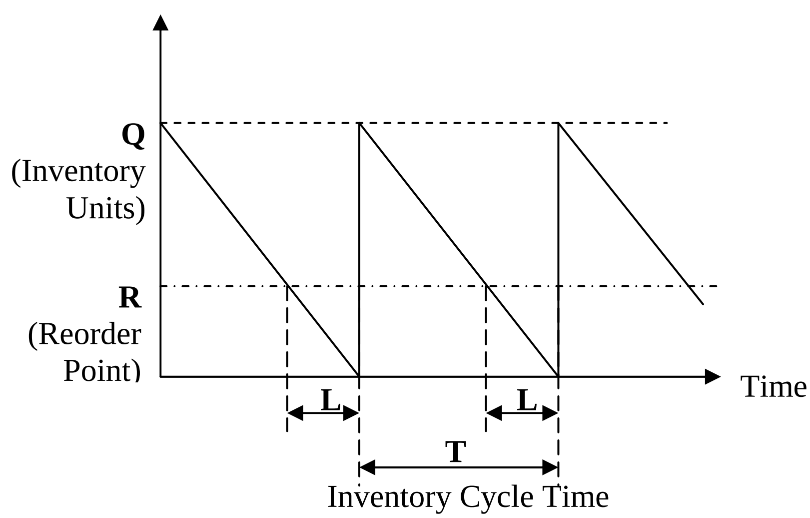

Figure 5. Basic EOQ Model Diagram.

The relationship between the two cost components – the annual holding cost and the annual ordering cost – and the quantity ordered, *Q*, are illustrated in the Figure 6. As *Q* increases, the annual holding cost also increases. The annual ordering cost, however, decreases. The minimum cost is the point where the holding cost curve meets the ordering cost curve.

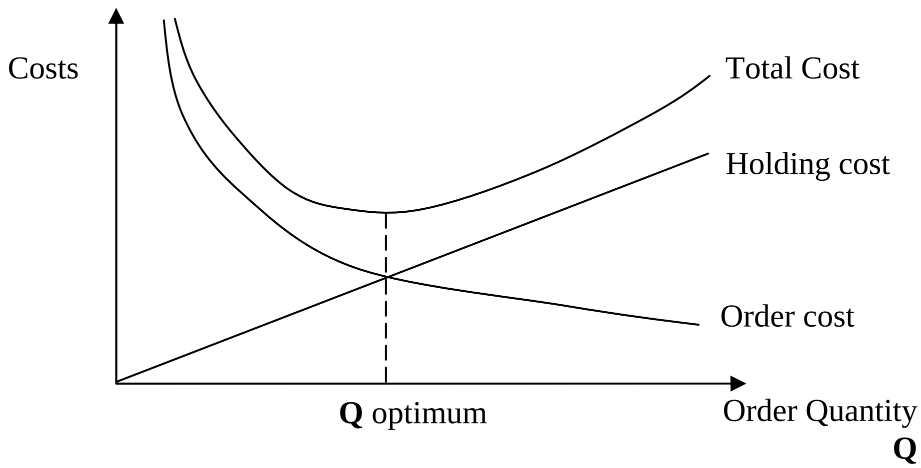

Figure 6. Relation between Cost and Order Quantity.

The basic EOQ model assumes that the demand is constant. In most cases, however, the demand is not constant. This variable demand may cause an *inventory stockout* – where the inventory is insufficient to meet the demand. The stockout usually occurs during the lead time.

To provide a level of protection against the stockout during the lead time, it is important to maintain a *safety stock*. The safety stock is the additional amount of inventory that has been calculated to meet the expected demand (Chase, Aquilano, Jacob, 2001). The objective of this safety stock is to minimize the probability of stocking out if the demand exceeds expectations. It does not, however, means that the safety stock is the additional order for every original order. Instead, the safety stock means a certain number of inventories the warehouse still hold when the materials ordered arrive. In other words, the safety stock can be defined as inventory on hand to cover the uncertain demands.

There is a strong consideration to maintaining an extra inventory, namely that it would create additional cost and higher carrying costs. Therefore, the safety stock should not be set high. To calculate the reorder point *R* with the variable demand, however, is similar to the method of calculating *R* in the basic model. The difference is that in the

circumstances where the demand is uncertain, safety stock is added. The equation for reorder point *R* is as follows:

$$Reorder\ Point = Mean\ Demand\ over\ Lead\ Time + Safety\ Stock$$

$$R = dL + z\sigma_L$$

where:

R = *reorder point*

d = *average demand*

L = *lead time*

z = *standard deviation for the desire of not stocking out*

σ_L = *standard deviation of usage during lead time*

An example for this equation is given using an item which has uncertain demand in aircraft maintenance operations. This study uses rivets (used to stick two or more metal sheets together) since there are no scheduled maintenance operations to repair the damage on the fuselage. The data for the item is as follows:

Demand per year (D)	=	600 pieces/year
Cost per order (A)	=	$ 100
Holding cost per unit/year (h)	=	10¢
Lead time (L)	=	3 months or 0.25 year
Standard deviation	=	20 units

Due to military operation frequency, the maintenance sections desire the service level of at least 99%; that means the probability of item stockout is 1% (0.01). The working days assumed 300 days each year. The calculation to determine the optimum *Q* is as follows:

$$Q = \sqrt{\frac{(2)(100)(600)}{0.1}}$$

Q = 1095.445 pieces, rounded up to 1096 pieces

The average demand (m) of rivets over lead time = (600) (.25) = 150 pieces

Standard deviation of demand over lead time (σ_L) = $20\sqrt{.25}$

= 10

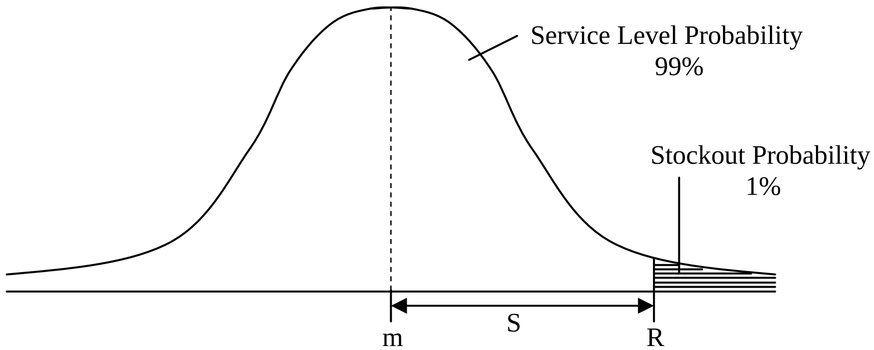

Figure 7. Distribution Curve.

Using the table for the normal probability, the value of z that gives the stock-out probability of 0.01 is 2.33. Therefore:

Safety stock (S) = $z\,\sigma_L$

= (2.33) (10) = 23.3 → rounded up to 24

Reorder point (R) = m + S

= 150 + 24

= 174

From the calculations above, an order for 1096 rivets must be made whenever stock level (stock on hand plus stock on order) is at 174 pieces. There is a safety stock of 24 pieces of rivets just in case the order cannot arrive on time.

Figure 8 illustrates the inventory replenishing process using the EOQ model with safety stock.

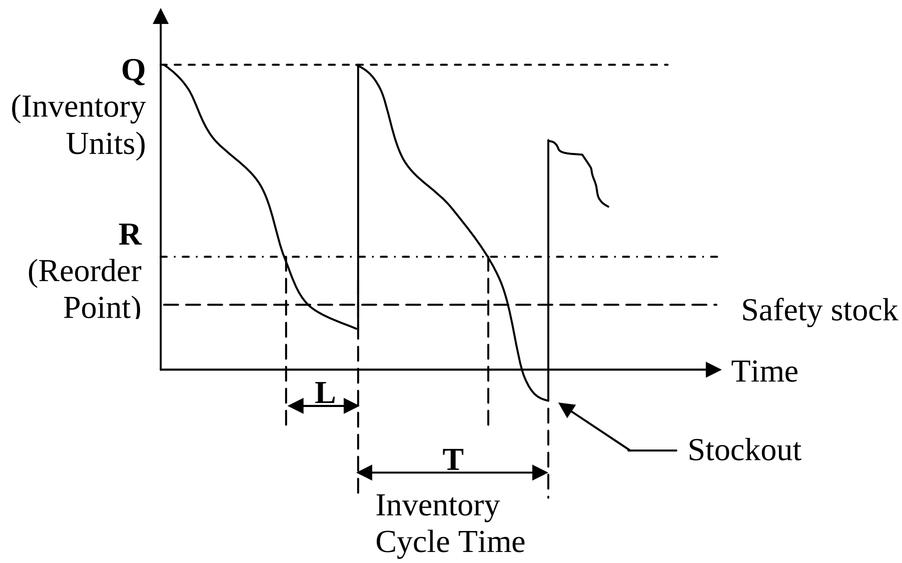

Figure 8. EOQ model with safety stock

C. MATERIAL REQUIREMENT PLANNING

The Material Requirement Planning (MRP) model is used to calculate the materials, or sub-assemblies required by the finished products, or bigger components. This model heavily depends on computer technology to perform and coordinate the whole inventory management. The information between each element of the MRP is always current and conveyed through the information system enabling it to maintain data accuracy and support resource planning and control. This process is important for the purchase orders and production and shop jobs.

The basic concept of the MRP is to have stock when it is needed and have none when it is not needed (Tony Wild, 1997). Conversely, the EOQ model is used to forecast the independent items' demand because of uncertain circumstances. Orickly (1974) says that the dependent demand should not be forecasted since the dependent demand can be calculated. The calculation is based on a master schedule. As a result, this master schedule level exists to forecast the uncertainty demands (Wight, 1974). The uncertainty exists for the demand of the finish goods. If the demand for the finished goods is known or can be forecasted, the master scheduled can be created and then the inventory stock can be reduced accordingly.

The MRP system consists of a set of item inventory records, decision rules and procedures – linked logically – and coupled with the computer software programs to make those records always up to date. This model is the thoroughly input and output relationship. The input elements for the MRP are as follows:

1. Inventory Status Records

The inventory status data is comprised of the individual item inventory record that contains information of inventory level on hand, outstanding orders, demand and lead time that are required to determine the net requirement. These data is kept up to date by continually updating the materials traffic in or out of the warehouse. The inventory status record also contains the planning elements – item lead time, routing and safety stock level – which are used to determine the size and the proper time to make an order. Any change in one or more of these planning factors will change the inventory status.

Orickly (1974) formulates the basic equation for this inventory status record as follows:

$$A + B - C = D$$

where: A = quantity on hand

B = quantity on order (outstanding order)

C = quantity required (gross requirement)

D = quantity available for future requirement

This equation can only solve the quantity and type of inventory required and not the appropriate time to place an order. Therefore *the time phasing* should be added. The time phase format – or scheduling – will not only determine the time the order should be placed, but also track the open order to see when it is actually needed (Wight, 1974). The time frame can be formatted into weeks or months.

The materials required to repair an SA-330 or AS-332 helicopter main rotor head's *spindle-sleeve* component is shown as an example.[9] It required a set of *seven-*

[9] This is a component in the main rotor system which holds the main rotor blade. This component is interchangeable between those two helicopter types. Each main rotor holds four spindle-sleeves.

bearing stack each time the *double-lip seal* leaked and needed to be replaced, an *anti-dust ring* – a protection cover that protect the moving component from the dust – and an *O ring*.

The example below is given for the materials required to repair twelve main rotor head's spindle-sleeves during the medium level maintenance for a six-month period. Thus the status of the inventory might appear as follows:

Seven-Bearing, Stack:		*Double Lip Seal:*	
On hand:	*11*	*On hand:*	*9*
On order:	*3*	*On order:*	*4*
Required:	*12*	*Required:*	*12*
Available:	*2*	*Available:*	*1*

Anti-dust Ring:		*O ring:*	
On hand:	*7*	*On hand:*	*4*
On order:	*7*	*On order:*	*9*
Required:	*12*	*Required:*	*12*
Available:	*2*	*Available:*	*1*

It seems that the material is sufficient to cover the gross requirement to perform the maintenance work on those twelve main rotor's spindle sleeves. All of the parts required indicate that the availability is positive after the process. When the time frame is applied, however, it is not as simple as it looks. Figure 9 illustrates the example of the time frame format for the inventory status record.

Month	**1**	**2**	**3**	**4**	**5**	**6**
Seven Bearing, Stack						
On hand	11	7	7	3	3	3
Open order due	*				3	
Quantity required	4		4	4		
Available	7		3	-1		
Double Lip Seal						
On hand	9	5	5	1	-3	1
Open order due	*				4	
Quantity required	4		4	4		
Available	5		1	-3	1	
O ring						
On hand	4	0	0	0	-8	1
Open order due	*				9	
Quantity required	4		4	4		
Available	0		-4	-8	1	
Anti-dust Ring						
On hand	7	3	3	-1	-5	-5
Open order due		*				7
Quantity required	4		4	4		
Available	3		-1	-5		2

* = order is placed. Lead time for all items is 4 months

Figure 9. Time Phased MRP

The time phase format shows that the availability of the *O ring* and *Anti-dust Ring* are negative in the third month and all four components are negative in the fourth month. To avoid the imminent stockout, all of the open order should be rescheduled to be completed in the third month.

2. Master Schedule Planning (MSP)

Master Schedule Planning or MSP is the prime input for the MRP system. It contains not only the planned products and specifies the output of operations, but also orders for the item from external sources – the original equipment manufacturer. The main purpose of this system is to translate the schedule into individual component requirements.

Orickly (1974) says that the MSP is stated in terms of end items. This means that the MSP is planning and scheduling the stock of finished goods or products, by period and quantity. It is not designed to carry the individual parts. In short, it expresses the overall plan for the operation.

Even though it is always mentioned as finished goods or products, the end product for the Indonesian Air Force can be a helicopter maintenance production or its components. The end product can be a helicopter's major components such as engines, main gearboxes, main rotors, etc. that are repaired by the helicopter maintenance units, or the helicopter itself when it comes to the periodic maintenance.

3. Bill of Material (BOM)

Bill of Material, also known as product structure file, is a list of subcomponents, parts or materials which are needed to assemble the end product (Tony Wild, 1997). A bill of material would show the main rotor at the highest level (as a single main component) or at lower level as subcomponent or subassemblies.

In the aircraft maintenance publication, there are books containing the parts, components and subassemblies lists which are called IPC (Illustrated Part Catalog). The books illustrate the aircraft and its main components, components' sub assemblies, down to the smallest parts such as screws, nuts, washers, safety pins, etc. The concept is the same except that it is not designed to produce or to assemble parts or subcomponents into an end item. It contains the information on the relationships of components and subassemblies which form the final assemblies. These components and subassemblies are identified by an identification code such as part number and the quantity per item.

The example structure of the bill of material for a helicopter is illustrated in the Figure 10 below.

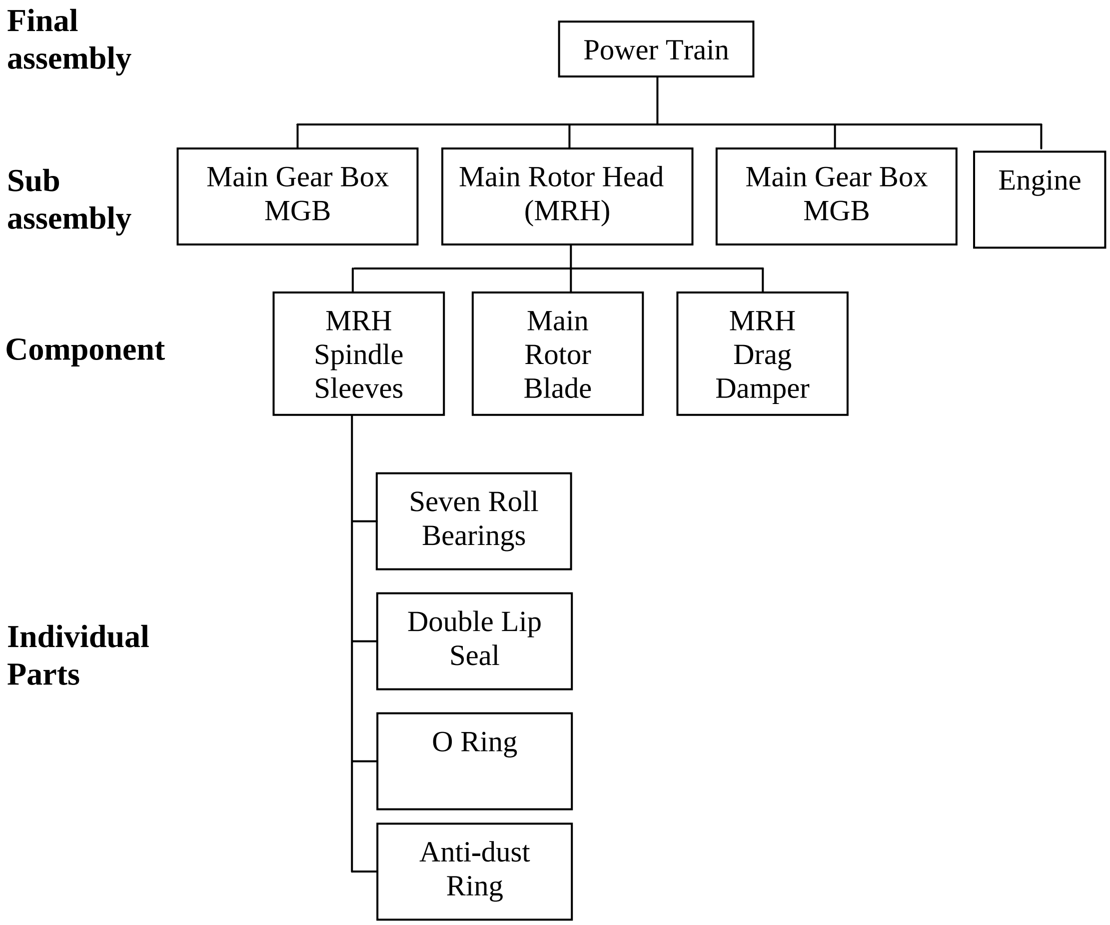

Figure 10. Product structure

4. Forecast for the independent demand items

Even though the MRP is designed to calculate the inventory of the dependent demand items, the independent demand items are still important since there are lots of items which are not directly related to the finished goods. The independent demand items forecasting is used as input to the MRP system. The forecasting can be done using a separate system outside of the MRP program, or a statistical program can be added to the system to perform a separate calculation (Orickly, 1974). The items with independent demands are categorized as item gross requirements.

The input and output relationships in the MRP system are illustrated in Figure 11 as follows:

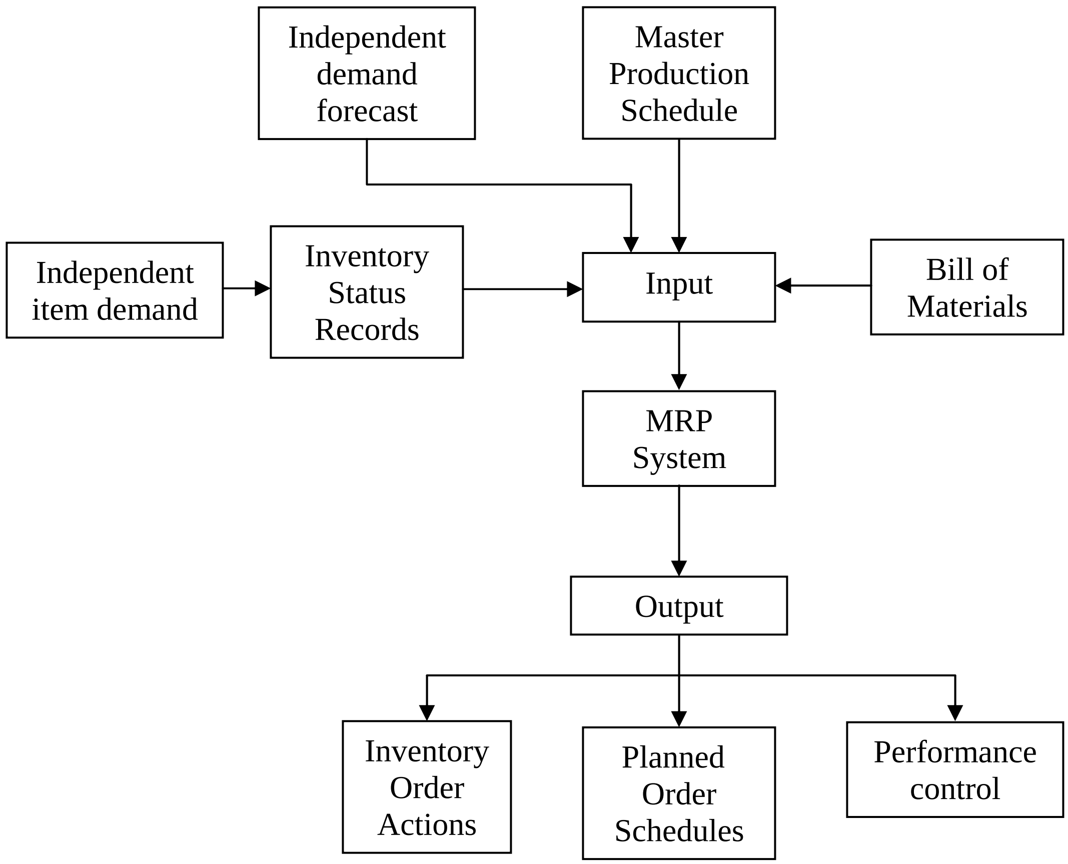

Figure 11. MRP System Relationship.

D. JUST IN TIME

Just-In-Time (JIT) is an inventory strategy designed to reduce the inventory stock level and its associated costs as low as possible. The JIT model allows manufacturing companies to reduce the inventory stock level to the minimum and encourages removing all surpluses from the warehouse. JIT was used by the Ford Motor Company in the early 1920s before being adopted and publicized by the Toyota Motor Company. Initially, Toyota did not call it JIT. Instead they called the system Toyota Production System (TPS). This model became an international method to many industries in many countries, such as Kawasaki Motor Corp., Chrysler, Hyundai, General Electric, Hewlett-

Packard and Dell (Yasuhiro Monden, 1986). The JIT model makes those companies' production operations more efficient, cost effective and customer responsive.

The JIT model is ideal for a manufacturing company which has a stable market, consistent demand pattern, and local as well as reliable and dependent suppliers.[10] The idea behind the invention of JIT is to have the supplies the company needs at the exact moment the supplies are needed. Its philosophy is to set the inventory stock level to zero (no buffer or safety stock) and build a close cooperation with goods and services suppliers (Tony Wild, 1997). Therefore the transportation aspect has a significant effect on the JIT system. The supplier's locations are important; therefore the JIT encourages the company to utilize local suppliers in order to ensure close cooperation. JIT model not only requires more frequent deliveries, but also emphasizes low transportation costs.

The continuous and frequent delivery of supplies and stock replenishment will decrease the transportation cost which in turn will decrease the overall costs. Tony Wild (1997) says, "The transportation cost may be decreased if the shipment is charged by weight, which means if the order volume for a specific item is small, then the extra room can be used by other items." The combination of various items in each shipment can compensate for the reduced amount of the bulk order. The cost can also be reduced if the shipment is charged at a flat rate. The transportation cost, however, may increase if the batches of items are purchased from various suppliers and the delivery is arranged separately.

The JIT is based on interdependent systems, which means that each system relies on other systems. This interdependence, however, can be a weakness for this model. Because of this interdependence, which is usually strong, the supply chain is vulnerable to any disturbances. The entire supply chain will be quickly disrupted if it is disturbed by any uncontrolled circumstances, such as labor strikes in the supplier's company, natural disasters (e.g. Katrina or tsunami), or interrupted supply lines which cause delays in delivery. The JIT model has very little inventory to anticipate such emergency situations. The low inventory is the reason for the reduced costs, however, on the other

[10] This is in contrast with the demand in uncertainty.

hand, it also puts the companies in a vulnerable position by not having sufficient safety stock to react and keep the supply chain moving during unforeseen events.

To prevent a disturbance it is important to have a reliable communication and information system between the companies and the suppliers. The reliable communication and information system will eliminate, or at least minimize, the inability of the company to get the right amount of supplies needed to keep the JIT system running well. Good communication and information flows will also prevent the tendency to keep a high stock level. High stock level may be a result of unreliable and unpredictable deliveries from the suppliers (Hutchins, 1999).

E. CHAPTER SUMMARY

Economic Order Quantity or EOQ is a model to forecast demand in uncertainty that usually occurs in the Air Force maintenance operations. It is best used to cover the material supplies required for unscheduled maintenance operations which cannot be predicted. For example, aluminum sheets and rivets or other fasteners required for repairing fuselages, tires changes, windows glass replacements, electric brushes for the engine starter motors, etc. This model can reduce the carrying cost because the inventory in the warehouse can be set to a low level. It can also avoid unnecessary reordering costs for the materials which are expired because of excessive amount purchases in the past.

Material Requirement Planning or MRP is a model to calculate (in contrary to "forecast" of the EOQ model) the materials requirements based on a certain demand. It is best used to calculate items or sub-assembly for helicopter's main components. The focus for the material acquisition plans is on the main component's maintenance scheduling. The only forecasting procedures are during the master schedule planning where the demands for the main components are forecasted. The MRP links the assemblies or subassemblies components' structures and stock level information in the inventory status as well as independent demand items, with the master scheduling plans. This model relies heavily on computer technology to perform and coordinate the whole inventory management in order to maintain data accuracy and support resource planning and control.

The Just-In-Time inventory model also offers the option to minimize costs. This model enables the company to purchase and receive the materials just before they are needed. Therefore, this model offers the possibility to reduce the inventory costs to a very low level. JIT helps the company prevent obsolete inventory; thus, relieving the company from the unnecessary work of managing idle parts. The model is ideal for profit seeking companies which have stable market, consistent demand pattern, and reliable as well as dependent suppliers.

The JIT inventory model, however, also has weaknesses. First, because of the interdependencies in the JIT system, any uncontrolled and unpredicted interruption in the supply lines can disrupt all links in the chain. This could happen because the companies do not have the safety stock (or if they have it, the stock level is very low) to compensate for the emergency. Second, there is a risk because the JIT model relies heavily on the communication and information systems. If the systems crash, the company cannot get the right amount of supplies from the suppliers. Therefore, the company should always have a backup system in place to help prevent the disaster caused by a communication breakdown. These weaknesses of the JIT inventory model are very important to recognize.

IV. TRANSFORMING BUSINESS PROCESSES

A. INTRODUCTION

This chapter discusses the literature review pertaining to transforming the business processes. Section B describes the Business Transformation. Section C describes the Business Process Reengineering. Section D discusses the Web-based Business. A summary is provided at the end of the chapter in the section E.

B. BUSINESS TRANSFORMATION

Information and communication technologies have improved the way business is done. The traditional business that relied heavily on paper-based information and work processes has been replaced or at least augmented by the web-based business system. The transformation to the web-based business also determines the future business' competition strategy. Porter (2001) says that many companies that succeed will be ones that use the internet (or e-business) as a complement to traditional ways of competing. Furthermore, he says that the key issue in keeping the business competitive "is not whether to deploy internet technology but how to deploy it, because internet technology provides better opportunities for companies to establish distinctive strategic positionings than did previous generations of information technology."

In e-business, the company's value chain is positioned behind its web page. Norris et al (2000) said that "the value chain encompasses an array of business processes that create value by delivering goods and services to customers." Porter (2001), in his article "Strategy and the Internet," explains that "value chain is a framework to identify and analyze all activities which affect both a company's cost and the value delivered to buyers." Generally a business company's value chain consists of product planning, procurement, manufacturing, order fulfillment, service and support. Many companies extend their control over the value chain as far back as possible. They control the processes from raw materials that are used in their products until the finished goods transported to the end users (customers). Figure 12 illustrates the simple value chain.

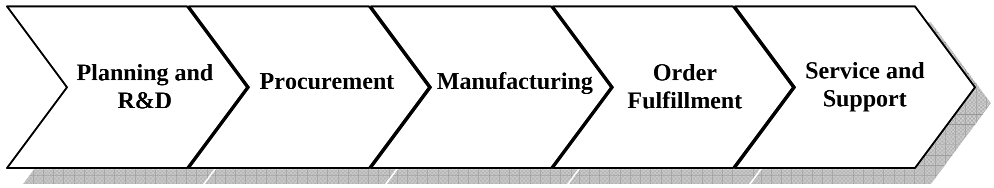

Figure 12. Simple Value Chain.

The collaborative use of information technologies leads to the use of electronic supply chain in the value chain (Norris et al, 2000). When companies view their business partner as a strategic asset, this will build trust and create integration among trading companies which in turn generates speed, agility and reduced costs. Furthermore, information technology enables the companies to share information across the supply chain which can become a substitute of inventory; therefore that information must be managed as “normal” inventory with proper monitoring. This extended enterprise will change the way business is done as individual companies will not compete against one another, but will form a business group. Figure 13 illustrated the value chain with extended enterprise.

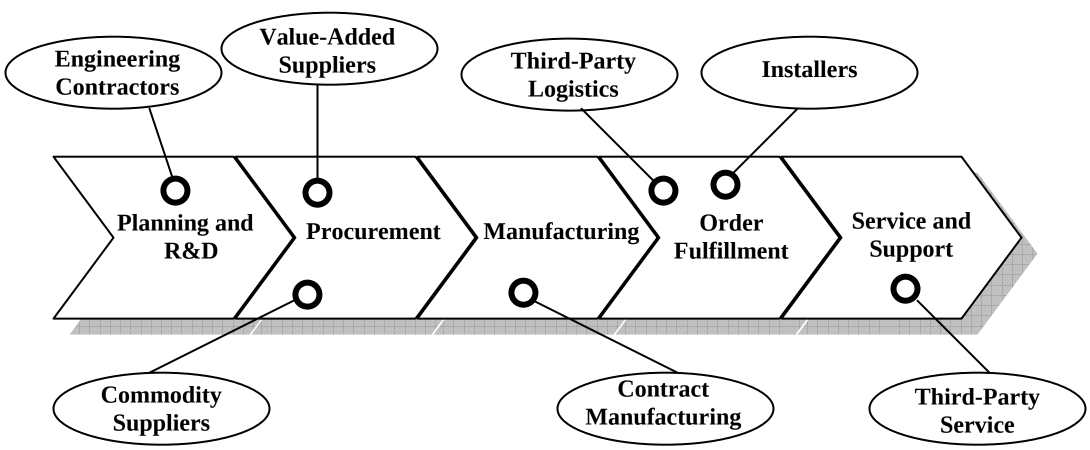

Figure 13. Value Chain of Extended Enterprise.

To change the traditional business environment to an e-business environment, however, requires a major organizational change in the strategic and operational issues in technology, business processes and the people (Norris et al, 2000). Norris also notes that there is difficulty when the new ways of business challenge the basic assumptions of a business culture. Change is hard for most people since it usually brings with it uncertainty. Some people will feel confused, alarmed, angry, or alienated toward transformation. This situation requires proper management. Duck (1993) in her article "Managing Change: The Art of Balancing," says that managing change is not like operating a machine or treating the human body, one ailment at a time. She explains that, in managing change, the critical task is to understand how the parts balance one another, how changing one element affects the rest, and how sequencing affects the whole structure.

Regarding the effects of change in a business organization, Norris et al (2000) explained that the most difficult to manage is the people. Table 1 illustrates the issues matrix when a company engages in a comprehensive e-business effort.

Impact on Business (Low → High)

	Technology	**Process**	**People**
Strategic	• Enterprise Architecture • Supplier Partnership • Role of Integrator	• Ownership • Design • Enterprise-wide (End to End)	• Change Management • Loose/Tight Controls • Outsourcing • Executive Sponsorship and Support • Aligning on Condition of Satisfaction • Overarching Objectives
Operational	• Product Selection • Product Support • Implementation/ Installation • Budgets	• Change Control • Implementation/ Support • Fluidity • Budgets	• Recruitment • Retention • Alignment • Knowledge Transfer • Budgets

Low — **Level of Difficulty/Time to Resolve** — High

Table 1. E-Business Organizational Issues Domain and Level Matrix.

To manage the changes affecting people, Beer and Nohria (2000) explain the two basic theories of change:

a. Theory E, which emphasizes economic value and is measured only by shareholder value, and

b. Theory O, which emphasizes corporate culture and human capability development, trust building and emotional commitment to the company through teamwork and communication.

Table 2 illustrates the detailed differences between the two theories and what an integrated approach might look like.

Dimensions of Change	Theory E	Theory O	Theories E and O Combined
Goals	maximize shareholder value	develop organizational capabilities	explicitly embrace the paradox between economic value and organizational capability
Leadership	manage change from the top down	encourage participation from the bottom up	set direction from the top and engage the people below
Focus	emphasize structure and systems	build up corporate culture: employees' behavior and attitudes	focus simultaneously on the hard (structures and systems) and the soft (corporate culture)
Process	plan and establish programs	experiment and evolve	plan for spontaneity
Reward System	motivate through financial incentives	motivate through commitment—use pay as fair exchange	use incentives to reinforce change but not to drive it
Use of Consultants	consultants analyze problems and shape solutions	consultants support management in shaping their own solutions	consultants are expert resources who empower employees

HARVARD BUSINESS REVIEW • MAY–JUNE 2000

Table 2. Comparing Theories of Change.

Furthermore, Kotter in his 1995 article "Leading Change: Why Transformation Effort Fail," explained eight steps to transform the organization as follows:

- Establish a sense of urgency by examining market and competitive realities, as well as identifying and discussing crises (existing and potential) or major opportunities.

- Form a guiding coalition with enough power to lead the change effort and encourage teamwork.

- Create a vision to help direct the change effort and develop strategies to achieve it.

- Communicate the new vision and strategies.

- Empower others to act on the vision, remove the obstacles to change which seriously undermine the vision and encourage risk taking and non-traditional ideas, activities, and actions.

- Plan for and create visible performance improvements, and recognize and reward employees involved in the improvements.

- Consolidate improvements; change the systems, structures and policies that don't fit the vision, and hiring, promoting, and developing employees who can implement the vision.

- Institutionalize new approaches and anchor the changes in the company's culture.

Kotter said that failure to do these eight steps or skipping some would lead to an unsuccessful transformation.

Adams et al (1984) also recognized that transformation requires structural and procedural changes in at least some of the basic systems of an organization and explains the indicators that transformation is occurring as follows:

- The process of transformation results in a radical progression of the organization's capabilities.

- The process of transformation leads to an alignment or linkage with larger systems and larger objectives than those in the past.

- The process of transformation may be characterized by strong vision and development capabilities, or by a sense that things are out of control, or a combination of both.

C. BUSINESS PROCESS RE-ENGINEERING

The concept of Business Process Re-engineering (BPR) was very popular in the 1990s. BPR brings about radical redesign of broad and cross functional business processes with the focus being on *what the business process should be*, and not *what the business process is* (Davenport and Short, 1990). The radical redesign combined with fundamental rethinking of business processes, "back to the drawing board" approach to organizational change, has a clear objective that is to achieve a giant leap of improvements in critical performance such as cost, product quality, service, and speed by eliminating non-value added activities.

The term Business Process Reengineering itself was formed from two elements; the business process and the reengineering. Both elements mean reengineering or redesigning the business process. To provide a clear understanding of the business process and reengineering, this research discusses these two elements as follows:

1. Business Process

A business process is a series of activities that provide value to the organization and its customers. Davenport and Short (1990) defined business process as "a set of logically related tasks performed to achieve a defined business outcome." In other words the business process can also be defined as a series of steps and interactions in an economic organization to process inputs (raw material from suppliers) using certain methods to produce goods or services as the output (to be used by customers). The process to accomplish the tasks and achieve the outcome may be a simple method comprised of one or two steps or may be a complex method involving tens or hundreds of smaller processes, each consisting of several steps. Each small process, or sub-process, in a complex business process interacts with higher processes through a chain of inputs and outputs. The links between those small processes in a larger business process leads us to consider them as the workflow in the organization to meet the customer's demand.

Davenport and Short (1990) considered that the business processes have two important characteristics:

- **Customers:** The business processes have defined business outcomes and there are recipients who will receive these outcomes. There are two types of customers of the business process. First, the customer may be the end user or buyer who uses the final products, in the form of services or goods produced by a company. This type of customer is an external customer which has no direct effect on the business process. The only effect from the external customer is the effect on the market demand. The other type of customer is the "internal customer" who is within the business process chain as a part of the business organization. This type of customer uses the output from the prior business process as its input.

- **Cross organizational boundaries:** The processes usually occur across or between organizational sub-units. For example, the customer of a sheet metal section in an aircraft manufacturer is the fuselage assembly line, which in turn will send its product (airframe) along with other component production lines to the next customer: the final assembly line. The final assembly line, which will install all of the aircraft components and engine, requires the components to be delivered on time so it can process and deliver its product (complete aircraft) to its customer, the marketing department. The buyer of the aircraft is the final customer of the process.

2. Re-engineering

Davenport (1998) said that the origin of reengineering is "to seek a better way to do work." Tsai (2003) said that "reengineering requires process thinking." Therefore, the term reengineering or redesigning a business process can be interpreted as a complete or total rethinking of a current business process in order to create better integration with other processes and to enhance the relationship between suppliers and customers.

There are two keys to a successful reengineering or rethinking effort: a) disengaging from the current practice constraints and b) enhancing the continual learning process (Tsai, 2003). It requires creative thinking about the value chain in current business processes in order to sustain a competitive advantage. Therefore, reengineering

can be called a radical way of identifying the desired output of the business process and designing the best possible process to produce the outputs. Davenport (1995) said that reengineering means “the radical redesign of broad and cross functional business processes with the objective of order-of-magnitude performance gains.”

The concept of reengineering is not new since the idea had already emerged before 1990 (Davenport, 1995 and Tsai, 2003). The idea to improve business processes and to manage them mainly comes from the business quality improvement or business process improvement literatures. The concept became new when the previous idea was synthesized in a new way emphasizing the utilization of information systems. Hammer (1990) said that information technology “should not be used to automate the existing process but to enable a new one.”

The essence of reengineering is to remove the outdated rules and fundamental assumptions which are the basis of some business operations (Hammer 1990). He recognized that many businesses are still focused on control which leads to a control system which transfers information up the hierarchy to the decision makers who presumably knew what to do with that information. This pattern has become so ingrained that it is still used by these companies regardless of the drawbacks. Therefore, Hammer emphasized challenging the old assumptions and putting aside the old rules that made the business performance low. Furthermore, Hammer recognized the principles of reengineering and summarized them as follows:

- Organize around outcomes, not tasks.
- Have those who use the output of the process perform the process.
- Subsume information-processing work into the real work that produces the information.
- Treat geographically dispersed resources as though they were centralized.
- Link parallel activities instead of integrating their results.
- Put the decision point where the work is performed, and build control into the process.

- Capture information once and at the source.

When the two elements of BPR are combined, it proposes a new commitment to the redesigning of business rules, processes, procedures, organizational structure changes, and repositioning of the corporate strategy. The BPR concept inevitably conflicts with old ideas and practices which were already established. Many businesses cling to inherited systems and processes simply because those are the one they have always used. As mentioned in Section B, it is hard to replace the established business process with a new method having more uncertainty. This is especially true for those who feel comfortable with the former business process and do not want to bother themselves to start a new way which seems unclear. BPR reveals the possibility for different assumptions, philosophy and theories of the conventional and traditional practices. It discards the obsolete rules and assumptions and replaces them with a process that combines the current market demands and emerging information technologies.

In a traditional hierarchical organization, the divided and dispersed business processes combine with excessive information filtering through the organization structure and interfere with business responsiveness. It requires a large amount of communication and coordination within many layers of middle management to manage a ten-thousand-personnel unit in a traditional hierarchical organization. The information technologies help to transform or redesign the traditional way of thinking on how to run the business process in a traditional organization into information-based organization through cross functional processes. The transformation in turn enables the innovative way to add new values to customers in the form of improved product quality, cost reduction and increase the timeliness of the business process.

The emergence of the new technologies, especially the information (and also communication) technologies, has changed the way the business process is run. The redesigned processes "challenge the traditional work methods, job design, organizational structure and management thinking and practice" with the presence of information system and technology (Tsai, 2003). One may assume that an organization should be able to redesign its business process without the information technology involvement.

Many recent successes in BPR, however, would be difficult without the aid of information technology (Grover 1995). In order to ensure competitiveness, companies should improve their business processes by redesigning the organizational structures and work practices as well as transforming the business cultures, supported by sufficient information technologies.

The major role of information technology in business process reengineering is to facilitate the design of a new business process. The information technology is not simply creating new methods for performing the old processes. It is not enough to use the information technology only to improve the current processes. Instead, it is more important to determine how to use the technology to do the processes that are not already performed (Tsai, 2003). Information technology supports critical decision making processes. It also enables managers to work in different ways to accomplish the transformation from the dominant functional hierarchy of the Industrial Economy to the IT enabled network of the Information Economy (Davenport, 1995).

D. WEB-BASED BUSINESS

Since the late 1990s, companies have increasingly turned to internet and web based technology to forge a tighter link to their suppliers and customers (Norris et al, 2000). With the emergence of advanced information and communication technology and their derivative, web-based information technology, companies can share accurate information with their trading partners. Rapid advances in information and communication technology have made the geographical distances virtually disappear and enabled businesses to streamline the internal processes which in turn stimulate the development of cross-functional integration to facilitate the information exchange between functional areas and across supply-chain boundaries (Tsai, 2003). Only a short time after it appeared, the web-based information technology had created a big impact on business processes and their customers around the world.

Tsai (2003) said that "the *webification* of business processes as a result of the dramatic advances in information and communication technologies have made the geographically proximity an obsolete virtue." Geography was a key role in the past in

determining how business was done and who the competitors were. It is not uncommon for today's customers to meet the service or goods providers without any face-to-face interactions. The customers no longer have to search for (physically) the goods or services they need and compare prices. Even the role of intermediaries in traditional markets is depleted since that the sellers can deal with the buyers directly[11]. All of the processes can be done by using web-based procedures. Buyers are gaining new power while on the other hand the sellers also gain new opportunity to expand their business.

In this section, this research discusses elements of web-based business which are important for aircraft maintenance in the Indonesian Air Force.

1. E-Business

E-business means conducting business electronically by using information technologies such as internet, intranet or extranet. It involves not only the traditional business activities (selling or buying) but also interactions with the customers in business process services and collaborating with the suppliers and business partners.

E-business can also be interpreted literally as a merger of traditional businesses with internet technology. It improves business performance by using information technologies to connect suppliers and customers at all steps along the supply chain, enhancing marketing and making purchasing more efficient. Business players can also integrate order delivery, manufacturing, financial, human resources and other back-office systems. E-business significantly improves business performance by strengthening the linkage not only between businesses, but also between a business and their customers (Norris et al, 2000). It improves the communications between business partners and also between departments within the organizations as well as between the organizations and the customers. As a result of this improvement, customer loyalty also can be improved and in turn satisfied customers can become long-term customers.

E-business has become an integral part of supply chain management and has become a powerful enabler of supply chain integration across a wide range of industries.

[11] The role of intermediaries are replaced by the infomediaries: the groups which offer aggregated services, intelligent customer services or buying aids by converting data into usable information. Examples for this new kind of "intermediaries" are Orbitz, Amazon, and eBay.

Today's successful organizations are those who can work across virtual global networks and link members of the supply chain. Those who can respond quickly are gaining an advantage as the first movers.

Successful e-business implementation enables businesses to reduce the cost of manual labor, inventory handling and purchasing. It also reduces paper-waste by removing unnecessary paperwork; and reduces the transaction time since electronic payment can be done faster than the paper-based one. Integrated internet-enabled applications can help the companies align resources to deliver goods and services at the right time; therefore, the e-business can provide value to customers with a single integrated solution (Thoben et al, 2002).

2. E-Supply Chain

Many companies failed to recognize the significant cost savings and revenue opportunities by focusing only on the customer-facing applications of e-business rather than focusing on the improvement of the electronic supply chain (Norris et al, 2000). Furthermore, Norris explains six components of the supply chain. Those components are as follows:

- Supply chain replenishment. This component utilizes real-time demand and encompasses production and distribution processes to improve customer responsiveness.
- E-Procurement. This component uses web-based technology to support procurement processes, including requisitioning, sourcing, contracting, ordering and payment.
- Collaborative planning. The role of this component is to synchronize production plans and product flow by sharing the forecast of demand, and supply plan to meet this demand. Collaborative planning must be updated by customers and sellers based on information shared over the internet.
- Collaborative product development. This component enables multiple companies to be involved in product design and product development using e-

business to improve product launch success and reduce time to market. It also reduces the product development costs by tightly integrating and streamlining communication channels and product design standards.

- E-logistics. This component supports the warehouse and transportation management processes using web-based information systems so it optimizes the distribution with inventory tracking information.

- Supply webs. Norris et al predict that in the future all information, transactions, products, and funds will flow on supply webs to satisfy customer demand as alternative configurations to the traditional supply chain.

3. Enterprise Resource Planning

Enterprise Resource Planning or ERP is web-based information system software which enables businesses to share information with their trading partners up and down the supply chain. It is intended as a way to replace the legacy system in streamlining the information flow which runs physically parallel with goods, from raw materials to finished products (O'Brien, 1998).

The history of ERP began when the need to systemize and to streamline the information flow in manufacturing processes encouraged many businesses to adopt the Material Requirement Planning (MRP) software to determine the demand of the products (Wight, 1974). In the 1980s, MRP was developed in order to make the applications able to manage a wider range of production scheduling problems in resource planning including labor, material management and procurement, and transportation. As a result, the old MRP software was developed into Manufacturing Resource Planning II (MRP II). Finally, in the 1990s when many companies redesigned or reengineered their business processes, software developers created a more capable set of applications which could link all internal transactions better, called ERP (Norris et al, 2000). With the integration of the whole processes into a single software, it is hoped that ERP can optimize the company's internal value chain.

ERP can create a new business formation by replacing many legacy systems which store various data in different ways. It is an integrated system that acts as a hub of

an enterprise which is intended to support the existing business strategies. It provides the company with the flexibility to improve customer responsiveness and also provide better management for production and inventory. Norris et al (2000) states that ERP can obtain these objectives by providing a consistency of information and integrating the following business components:

- Resource planning, which includes planning and forecasting, purchasing, material management, warehouse, distribution management, accounting and finance.
- Supply chain management, which includes understanding demand and capacity and scheduling capacity to meet that demand.
- Demand chain management, which includes handling product configuration, pricing, contract and promotion.
- Knowledge management, which include creating a central data collection of the enterprise, business data analysis on this data, provide support for decision making process for leadership, and creating future strategies.

ERP connects and shares common data across the organization. It is a technological hub of a single enterprise which can be seen as a central processor of internal corporate information derived from order management, reporting, inventory, finance, logistics, manufacturing/maintenance, production, human resources and marketing/operation as illustrated in Figure 14. When particular data (for example, purchasing data) become available, the software automatically transforms the data into useful information and then calculates the effects of the transaction on other sections, such as inventory, financial, etc. In short, ERP organizes, codifies and standardizes the business' processes and data.

Figure 14. Example of Integrated Enterprise Resource Planning.

With some benefits in the form of reduced transaction cost due to the availability and accuracy of information and increased business process efficiency, the ERP, however, comes at a cost. Firstly, the price of the ERP software is not cheap[12]. Norris et al (2000) stated that this price is only 15% of the overall cost of implementing an ERP system as illustrated by Figure 3. Koch (2002) also recognizes the areas which cause budget overrun as follows:

a. Training expenses

b. Integration and testing the links between ERP packages and other corporate software

c. Customizing the core ERP software to fit the current business processes

d. Data conversion from the legacy systems to the new ERP

e. Data analysis to combine data from the ERP system and data from external systems

12 In June 2000, Nestlé SA signed a $200 million contract with SAP to install an ERP system for its global enterprise plus $80 million for consulting and maintenance. Source: CIO Magazine, May 15, 2002 issue.

f. Consultation fees

g. There is a risk of losing qualified and skillful personnel when the installation project is over and then in turn would end up in hiring them (or someone like them) back as consultants for twice their previous salaries.

h. The ERP implementation team cannot stop after the software is installed since they are needed to run the system for some times before the system is turned over to the sales people or manufacturing people.

i. Post-ERP depression because people can't do their job in a familiar way and haven't yet mastered the new way, causing business to go bad

Secondly, installing an ERP system requires a lot of time. The system itself requires at least six months to implement (Koch, 2002). Norris et al (2000) even stated that installing ERP requires more than 12 months in most cases. The bigger the company, the longer it will take to install and implement the ERP. Figure 15 illustrate the approximate time frame for ERP implementation[13]. Koch (2002) stated that in order to implement the ERP correctly, it is imperative that "the way you do business will need to change and the way people do their jobs will need to change too."

		Business Degree Process Change		
		Zone 1 Low	Zone 2 Medium	Zone 3 High
Business Complexity	High	12 – 18 months	18 – 36 months	24 – 48+ months
	Medium	6 – 9 months	12 – 18 months	18 – 36 months
	Low (Vanilla)	3 – 6 months	6 – 9 months	12 – 18 months

Figure 15. Time Frame for ERP Implementation.

13 From Fig.4, Vanilla ERP is a company or companies which has already implemented ERP and only requires software renewal and replacement (Norris et al, 2000)

Even though ERP is software, it has distinctive implementation characteristics compared to others. A business must do more than simply install the software, operate it and then wait for good results. Implementing ERP requires major changes or redesigns in organizational structure, culture, individual roles in the organization and the way business is done. Norris et al (2000) said that among the key drivers of process redesign is the need to improve the company's financial performance by improving operational performance. In many cases, this will lead to staff reductions or people being transferred to other areas.

E. CHAPTER SUMMARY

The way business is done has changed since the emergence of advanced information and communication technologies. Internet technologies have influenced the value chain in many businesses. In order to stay competitive and survive in the fast moving world, businesses must adopt the new technology and leave the legacy system behind. This step, however, will face some resistances from those who were comfortable with the old system and those who worry about the uncertainty of the future. The most difficult part is to change the people and culture. But the transformation is a must if the company is to survive. It can be reached by wisely managing the change in technology, process and people in the company. Once the transformation is accepted and executed, the company is ready for future steps.

The Business Process Reengineering concept brings the radical redesign and rethinking of business processes. It changes the way business is done from the legacy system to the new one which heavily employs information and communication technology. This concept works across functions and boundaries of the businesses and replaces the dominant hierarchical business processes with IT-enabled ones in order to improve the value chain between the supplier (seller) and customer (buyer).

With the emergence of internet technology, the information between trading partners can be shared faster. Web-based business enables businesses to improve their supply chain by virtually eliminating the geographical distances as well as enabling the

businesses to respond faster in the volatile market conditions. In addition, web-based business also reduces unnecessary paperwork.

Enterprise Resource Planning also eliminates the legacy system and improves the business performance by integrating order management, reporting, inventory, finance, logistics, manufacturing/maintenance, production, human resources and marketing/operation in a single software. It serves as a hub for those activities. The software, however, is not cheap and requires a lot of time to implement and run. But after it is properly implemented, the business process will improve and the goal to reduce costs and obtain efficiency can be reached.

V. BPR IN INVENTORY MANAGEMENT

A. INTRODUCTION

The goal of the Indonesian Air Force is to meet the demand of the customer, i.e. the whole nation: to maintain air sovereignty over national airspace. To provide this, the Indonesian Air Force through its Air Force Operation Commands utilizes aircraft – here the discussion is limited to the helicopter – and other weapon systems and equipment in the inventory, supported by the maintenance units. In order to support the effort to reach this goal, the maintenance units require the materials from the suppliers, either from local manufacturing companies or foreign companies. Therefore, the maintenance units are the service provider for the first customers – the Air Force Operation Command – which in turn will provides the service – in the form of airspace sovereignty – to the end customers: the Indonesian people.

The existing method employed in order to provide material for aircraft maintenance operations in the Indonesian Air Force is performed by calculating the material requirement based on the flying hours allocated for each aircraft type by the Air Force Headquarters. The total flying time is determined by the operational requirements to fulfill the Air Force mission to guard Indonesian airspace and to support any military operation other than war such as humanitarian missions. Based on these operational requirements, the Headquarters formulates and proposes the budget, and after it is approved by the Department of Defense it will be translated into flying time for the current year.

This chapter discusses the process of improving inventory management for aircraft maintenance in the Indonesian Air Force by incorporating the knowledge and information from Chapter III and Chapter IV. Section B presents an overview of the existing method used by the Indonesian Air Force to maintain its helicopter fleet. Section C discusses how to implement Material Requirement Planning as a way to improve inventory management to support the aircraft maintenance operations. Section D discusses the implementation of the Business Process Reengineering in the maintenance operation supply chain in order to improve inventory management in aircraft

maintenance operations. A chapter summary is provided at the end of this chapter in Section E.

B. THE EXISTING METHOD

The method used currently to determine the material demands does not require a complex computation. The method is a very simple forecasting method; it only adjusts the material requirement based on the previous year's flying hours. For example, in the Year 1 the Air Force's actual flying time was 5000 flying hours and required 200 pieces of item A for maintenance operations. In the year 2 the flying hours allocated is 6000 hours. Thus, the total amount of item A required for the maintenance operation is 240 pieces (the number is increased by 20% as the flying hour also increased by the same rate). Table 1 illustrates the example of the forecasting method for three different items for Years 1, 2, and 3, the last of which has an increase rate of 15%. Assuming that the objective of the forecasting is to determine material procurement for the Year 3 – the calculation and forecasting must be made in Year 2.[14]

	Year 1 (Last year)	Year 2 (Current Year)	Year 3 (Next Year)
Flying Hours (Allocated)	5000	6000	6900
Item A required	200	240	276
Item B required	40	48	56[15]
Item C required	120	140	161

Table 3. Currently Used Forecast Method.

[14] The assumption is based on the current practice in the Indonesian Air Force after collected the material requirements from the helicopter squadrons and helicopter maintenance squadron.

[15] The actual result is 55.2; the number is usually rounded up.

To determine the total amount of material that must be purchased to fulfill the maintenance operation in Year 3, the data obtained from the forecast is compiled with the material availability data in the warehouse. The data of material availability in the warehouse contain the amount of material left from the maintenance operations in the previous year. The margin between the material requirement and the material availability is the amount of material that must be purchased. Table 2 illustrates the example of the calculation process to determine the number of items that must be purchased to replenish the inventory.

Flying Hours	6900		
Materials	Material Availability in the Warehouse[16]	Material Required for Maintenance Operation	Margin
Item A	100	276	176
Item B	25	56	31
Item C	150	161	11

Table 4. Calculating Material for Year 4.

From the table, materials that must be purchased for Year 3 are item A: up to 176 units, item B: up to 31 units and item C: up to 11 units.

This simple forecasting method is adequate only if the flying hours which have already been planned can be executed without any deviation. This simple method, however, can be a hindrance to the Air Force which has so many "flexible" missions. The example above shows the inflexibility of the method. If the actual flying time highly exceeds the allocation, there will be a shortage of material. Otherwise, if the actual flying time is extremely below the allocation, there will be a surplus which often creates problems due to the material expiration date (especially rubber based material or its syntheses, such as "O" rings, tires, gaskets, etc.) which will lead to obsolescence costs.

[16] This is the material availability in the warehouse after the maintenance operation from the previous year (Year 2).

The Air Force has already experienced losses due to expired material.[17] This is not to mention the higher losses due to material unavailability which will lead to rush orders. When rush orders are made, the price will also increase because of the small order size, just enough to fill the requirement at that time and affected by the availability of funds. If the material should be purchased in a big amount while the number required are small, the residual amount might pile up in the warehouse until future use which is uncertain. Thus, another cost of obsolescence might occur.

In addition to the forecasting method, the Indonesian Air Force also employs a method which is basically similar to the Fixed-time Period Model of the Multiperiod Inventory System (Chase et al, 1973). This method, however, is only applied for aircraft fuel distribution. There is a fixed schedule to distribute the fuel to airbases regardless the residual amount in the airbases' fuel bunkers. The rest of POL components as well as other consumable materials are provided by request from the user (helicopter squadrons and the helicopter maintenance squadron).[18]

Furthermore, the Indonesian Air Force also organizes the materials into two groups: the "slow moving components" and the "fast moving components."[19] These materials are intended to replace or repair the failure components or parts of the aircraft. To manage these materials, the Air Force already uses the *Push-Pull Strategy* (Simchi-Levi, 2003) in managing its inventory, although not directly. The *Push* strategy is used to provide the materials based on the long-term forecast. The material provided is usually the spare parts which are not on the list of the Periodical Overhaul kits (PO kits)[20], i.e. the slow moving components. The *Pull* strategy is used to provide the material based on the maintenance demands. These materials are the spare parts on the list of the PO kits which are routinely used in periodic maintenance. Some of the spare parts or components which are not on the list of the PO kits are also managed using this strategy.

17 The total dollar value of losses in the term of dollar cannot be determined since the data collected vary widely.

18 Consumable materials are materials which are not part of the aircraft system. Sealant, glue, cleaner, rust remover, etc. all fall under this category.

19 Slow moving components consist of the materials which are not used frequently or the demand for them is low, while fast moving components are those in high demand.

20 The demand for the kits is dependent since the number of kits ordered is determined by the frequency of periodic maintenance.

These materials are the helicopter's components which are worn out quickly such as tires, the bearings in the power train system, the engine's starter motor's brushes, etc.

As discussed in Chapter 2, the communication lines to manage the information in the supply chain among helicopter units (including the maintenance squadron) in KOOPSAU I, the maintenance depot in the Air Force Material Maintenance Command and the Air Force Headquarters still rely heavily on paper-based communications, supported by the telephone lines and some telex and fax machines. Information sent using the post office or courier services might be delayed because of external issues. Moreover, it is time consuming to compile data from various sources. Therefore, there are risks of losing information or data accuracy during the compiling and delivery processes.

C. IMPROVING INVENTORY MANAGEMENT

The difficulties encountered in providing sufficient funds for the real needs of the military, particularly the Air Force, have been widely known. Defense structure is very expensive and should be carefully planned with enough consideration towards the availability of state funds and sustainability. These circumstances also apply in managing the inventory for the five types of helicopter in the Air Force arsenal (UH-34T Twinpac, SA-330J/L/SM Puma and AS-332C1/L1 Super Puma assault/transport helicopters, EC-120 Colibri and Bell 47G Soloy trainer helicopters) which are organized into three helicopter units in two separate Air Force bases under two different commands.[21] To improve the Air Force's inventory management in order to support the maintenance operations, there are two models that can be applied. The first method is The Economic Order Quantity and the second is the Material Requirement Planning. This research will focus on these two models to offer a different way to improve the Air Force inventory management than the currently used method.

[21] The third unit is training squadrons. The medium level maintenance unit is integrated in the squadron organization; therefore the unit is not required to send its helicopter to the Helicopter Maintenance Squadron which is located on the other Air Force Base.

1. Inventory Management Methods Application

The most appropriate option to organize inventory management for the aircraft maintenance operation in its current condition is the Material Requirement Planning method. This method will integrate the effort in material acquisition processes and at the same time track material circulation during the maintenance operation processes at various levels using information technologies.

The primary usefulness of the MRP method in the Indonesian Air Force is that it highlights the trade-offs involved in the decision making and provides the most feasible solution for inventory management. The advantage of the MRP method is that the inventory status is always up to date and real time. It also allows the Air Force to develop its maintenance organization in order to become the center of excellence of the Air Force and a model for the other services in managing their inventories. The disadvantage of the MRP is that it relies on information technology to convey information between each of input and output elements; therefore, it requires a computer network within the maintenance organization.

There are five elements which will play important roles in the proposed MRP system; thus opening an opportunity to redefine the critical roles of the two major commands (KOOPSAU I and KOHARMATAU), as well as the warehousing sections in the supply chain system. Those elements are as follows:

- Helicopter Subdirectory at the Aeronautic Directorate of the Logistic Department, Air Force Headquarters.
- Atang Sendjaja Air Force Base under KOOPSAU I, which has helicopter squadrons and a helicopter maintenance squadron in its command structure.
- DEPOHAR 10 under KOHARMATAU, which has the helicopter depot maintenance unit (SATHAR 16) in its command structure.
- Warehouses on Helicopter Air Base (GPL) and DEPOHAR 10 (GPD).

The responsibility of each section, unit or department in the MRP system is described below.

First, based on the flying hours for the helicopter fleet allocated by Air Force Headquarters, the Department of Logistics (DISLOG) at Atang Sendjaja Air Force Base – as a subordinate unit under KOOPSAU I – prepares the Master Production Schedule (MPS) for helicopter maintenance operations. The MPS describes the number of each maintenance type level which will be performed for the year (i.e., the number of unit level maintenance performed by the helicopter squadrons, or helicopter main component replacement schedules). The information pertaining to depot level maintenance would be sent to Maintenance Planning & Controlling Department (DISRENDALHAR) under DEPOHAR 10. After formulating the master plan, the DISLOG prepares the maintenance plans for unit level and intermediate level maintenance as well as main component replacement. Simultaneously, DISRENDALHAR of the DEPOHAR 10 prepares the depot level maintenance operation plans for the helicopter fleet.

The details of the master plans are translated by the units (Helicopter Squadrons, Helicopter Maintenance Squadron and SATHAR 16) into Bills of Material (BOM) to describe composition of the material required for each maintenance operation. Based on the maintenance plan, the helicopter squadrons' maintenance sections and helicopter maintenance squadron, as well as SATHAR 16, type-in the materials requirement list needed to perform the maintenance operations by employing the Illustrated Parts Catalog (IPC) books available in each unit. This step follows Orickly (1974) who said that explosion of requirement in MRP programs flows through component levels following the linkage specified in BOM structure. The information is then relayed to the higher commands through respective channels as BOM input.

Next, the Air Force Base's Department of Logistics as well as the Department of Maintenance Planning & Controlling under the DEPOHAR 10 forecasts and calculates the demand for the materials which are not in the scheduled maintenance kit list and the materials which are not directly related to maintenance operations. Materials which are not in the scheduled maintenance kit list include aluminum sheets, plexiglas windshields, fasteners (rivets, screws, bolts and nuts), and tires. Materials which are not directly related to maintenance operation include paint, fiberglass, resin, etc. The fiberglass and resin are used to mold the plexiglas into the windshield panel. Sometimes, however, those materials are also used to repair the main rotor and tail rotor blades.

The other input comes from warehouses at the Air Force base (GPL) and at the DEPOHAR 10 (GPD) which produces the inventory record files consisting of the individual item inventory records to determine the quantity available for future requirements and also prepares the independent item demand record files. The data are obtained from the material transactions or traffic in and out of the warehouses. As a consequence, the inventory in the warehouses must be updated constantly and instantly if any transaction occurs. Failure to do this will result in delays in the MRP processes or misinterpreted data during the process which in turn will create inaccurate inventory assessment in the higher level. In addition, the warehouses also play an important role in assisting the process to determine the independent item demands during the past. This information will be used to forecast and calculate the independent item demand for future periods. Economic Order Quantity (EOQ) method is employed here. With EOQ method, warehouses can determine the safety stock that must be maintain in the inventory and suggest replenishment once the inventory reaches the safety line. Orickly (1974) said that for the forecasting part in the EOQ, a separate system outside of the MRP software can be used. The forecasting processes can also use a statistical program that can be added to the MRP system to perform the calculation.

All input from KOOPSAU I and DEPOHAR 10 and the forecast for independent items, as well as the inventory status records from the GPL and GPD are then entered into the MRP system. The results from the calculations performed by the MRP are used to determine the order of material to replenish the inventory, plan the order schedule and control the performance. These three activities are performed by the Helicopter Subdirectory at the Aeronautic Directorate of the Logistics Department, Air Force Headquarters.

The ideal configuration is to put the MRP central processing unit at the Helicopter Subdirectory so that the output of the MRP can be used directly to determine the material procurement. Based on the output of the MRP system, the Helicopter Subdirectory prepares the material acquisition schedule proposal for the Department of Defense, since the procurement processes are under the authority of the DOD. Figure 1 below illustrates the information flow diagram in the proposed MRP system for inventory management in the Air Force's aircraft maintenance operations.

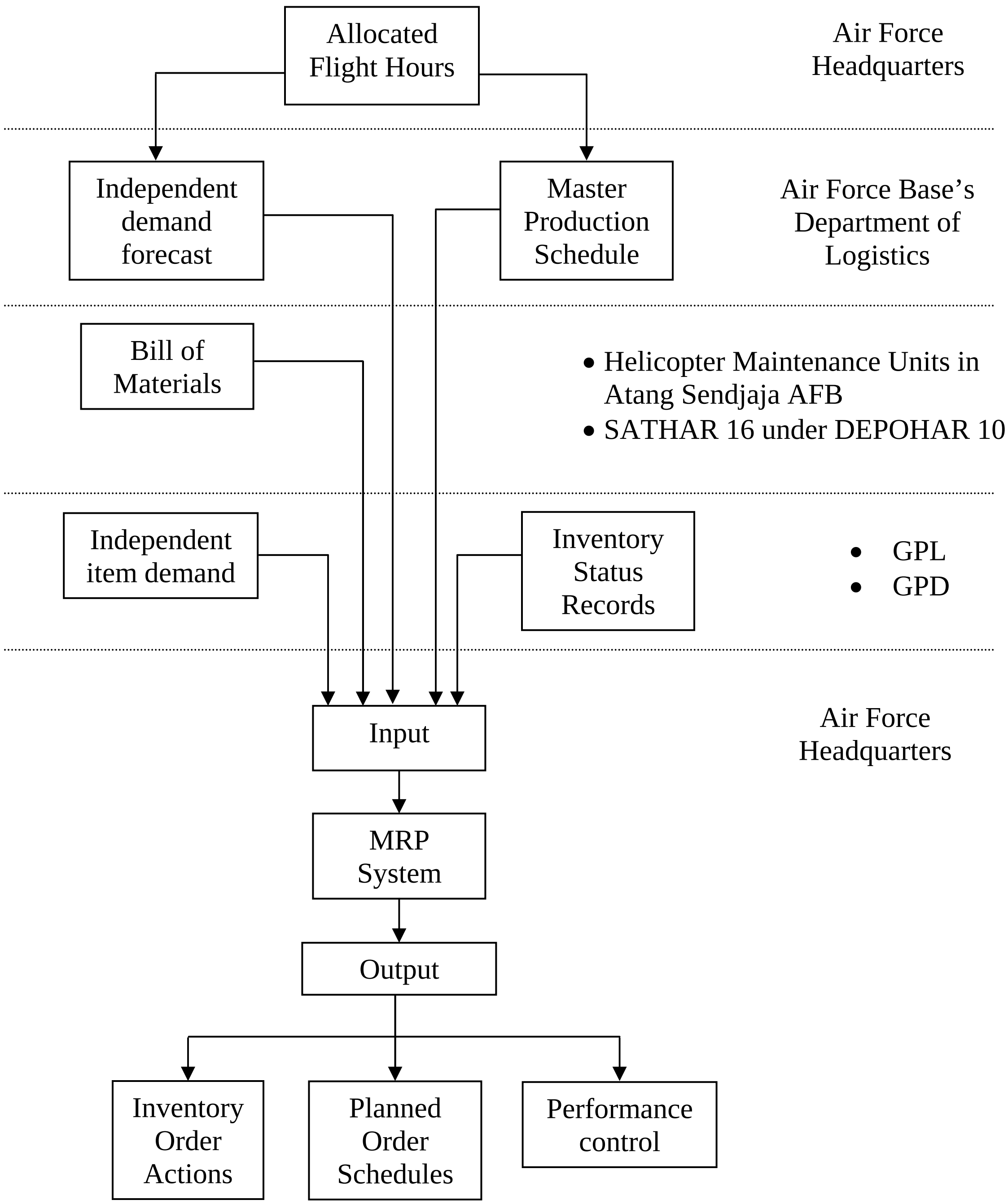

Figure 16. MRP Diagram

2. Web-based Inventory Management

The Indonesian Air Force had already been utilizing computers since the 1990s. Most of those computers, however, are still working as stand alone systems; this means

there are no links to connect one computer to another. All documents are kept either in desktops' hard drive or in various portable data storage devices.

The common practice currently used in the Air Force to share data or information between units in various command levels is by transferring the data via portable data storage devices (diskettes, CDs or thumb drives). These practices are not only incompatible with the real-time concept, but also cannot guarantee the safety of the information during transfer.[22] The data sent by this practice, however, still has to be authenticated by paperwork. Therefore, the technological aspect in the form of portable data storage devices is only a complement to the paper-based information system. In an MRP environment, these practices would render inventory management processes useless, or at least incapable of running properly.

This research emphasizes the role of the Helicopter Subdirectory as the core unit to process the input for the MRP system and execute the output of it; and the role of the KOOPSAU I as well as the KOHARMATAU in providing the input for the MRP system. To implement the MRP system effectively, the Air Force should abandon the current practice of transferring data via portable data storage devices and begin to install a web-based information system. The proposed method is by installing a Local Area Network (LAN) to enable secure information sharing within the Subdirectory.

The implementation of information technology will integrate supply chain networks thereby enabling sensing of information in the environment and timely dissemination that information throughout the organization. The information sensing and dissemination are important factors in inventory management. With information technology, the Air Force can connect directly to the suppliers with minimum intermediary involvement, which in turn will reduce the material procurement costs. In addition, information technology provides security and safety, to some extent.

In fact, the Indonesian Armed Forces already has a webpage which contains information, much of which is for public consumption, even though sometimes the webpage cannot provide sufficient information for the public because of the irregularity

[22] Diskettes or thumb drives may be damaged, stolen, lost, etc., or worse; the data are altered or modified during the transfer processes.

in information updating processes. For information technology security issues, the inventory management information system is not directly attached to the "public" military webpage. The Indonesian Air Force personnel who are in the inventory management businesses can still get access to their network through authentication codes.

The challenges for the Indonesian Air Force in setting up its web-based inventory management businesses can be identified as follows:

- Install the computers, including their peripheral equipment, throughout the organization and connect them to a network. The challenge for this factor is the computer price and installation costs. The price would be high enough if the Air Force chose to purchase branded computers to equip the network. It is not, however, as high as if the Air Force purchased the computers from the local supplier working in the same manner as Dell, Inc.[23] With customized equipment best suited to meet the MRP system requirements, the costs of computers can be reduced as low as possible.

- Integrate the computers into a network. This requires a connection system such LAN or WAN (wide area network). With proper connectivity, information and data can be disseminated faster through the network.

- Find the right software to run the MRP system. There are a lot of MRP system providers in the market. It requires a lot of effort to find the best MRP system which meets the specifications of the Indonesian Air Force inventory system for aircraft maintenance operations.

- There is no IT department in the Indonesian Air Force. The current Air Force's only web page was developed by a commercial information technology company and maintained by the Air Force Department of Information for public relations purposes. Therefore, to build a web-based business, the Air Force should form an Information Technology Department within its organization.

23 Dell purchases computer components from various suppliers and builds its product with customization options for the customers.

D. BPR IN THE MAINTENANCE OPERATION SUPPLY CHAIN

After having discussed the concept of Business Process Reengineering in Chapter Four, this thesis will discuss the possible ways to BPR the supply chain in order to improve inventory management. The aim of the BPR is to replace the legacy systems in the Indonesian Air Force which are not suitable with advanced technology.

The changes from the legacy system, however, will affect the organizational structure. First, adequate personnel with reliable information technology skills must be acquired. Second, the number of personnel who previously occupied a position in the supply chain will be reduced. Even though it is not unusual in the Indonesian military to transfer people from their previous working place, the reorganization and redesign the work processes often results in disgruntled employees. Tsai (2003) said that "reengineering efforts not only contend with technical and managerial enigmas, they must also deal with cultural, behavioral and organizational perplexities. A successful reengineering effort requires more than changing workflow and introducing new technology; it must also effectuate the human aspect of organization culture, become a learning organization."

The old way of doing business in the Air Force to provide the material required for aircraft maintenance often creates cost problems. The problems emerge since the Air Force still relies on the intermediaries' services. Almost all weapon systems and other military equipment are purchased through intermediaries.[24] The common logic is that the intermediaries have sufficient funds to pay the materials price purchased by the Air Force. When the state grants sufficient funds through the Department of Defense to the Air Force, it will be used to pay the intermediaries. This practice, however, has a certain degree of risk when the intermediaries mark up the original material price two or three fold since they are the ones who know the exact price.

To change this way of thinking, however, is not easy. The Commanding General of the Indonesian Armed Forces, General Endriartono said in 2004 that the role of the

[24] Intermediaries are commercial companies which provide services as a link to connect the military with the weapon systems suppliers. The military has no direct link to the weapon system manufacturer or other suppliers.

intermediaries to provide military equipment cannot be eliminated now since the state and military funds are insufficient to finance all the required military equipment.[25] He was, however, intending to conclude the role of the intermediaries in the future procurement of weapon systems and other military equipment and use the direct communication between states' leaders or "G to G" mechanism. This mechanism is ideal since it can improve the cost management side of the procurement of weapon systems and other military equipment.

In addition to the tendency to adopt the "G to G" mechanism, there is an effort to improve the acquisition of weapon systems and other military equipment with the "one gate" concept.[26] If the "one gate" option is realized, then it will open an opportunity to link directly to the material suppliers in foreign country as well as local suppliers with minimum involvement of the intermediaries. Moreover, with a direct link to the supplier, the effort to obtain the materials can be reduced significantly as well as the cost; thus making the process run more effectively and efficiently. Therefore, the MRP system should link with the Department of Defense who provide funds to finance the material acquisitions and act as the sole entity for the procurement processes.

Since the MRP system also links to the DOD, Business Process Reengineering (BPR) in the inventory management to support the aircraft maintenance operation of the Air Force's helicopter fleet would also change that organization. The implementation of the Material Requirement Planning system (MRP), which relies heavily on information technology, in helicopter inventory management, would create a major change in the Air Force organization. For example, as mentioned in Section C there is no IT Department in the Indonesian Air Force organizational structure. There is a Department of Electronics and Communications in the Air Force organizational structure. The main task of that department, however, does not consider advanced information technology. The Department of Electronics and Communications mainly handles the aircraft or ground unit electronic equipment, such as radar, communications radio, avionics, etc. as well as maintaining the internal telephone lines. The information systems alone would create a

[25] In an interview with Kompas newspaper on December 23, 2005.

[26] Material acquisition proposals are submitted by each service to the Armed Forces Headquarters (MABES TNI) for priority analysis. After that, MABES TNI submits the proposals to the DOD for procurement processes. (Republic of Indonesia Minister of Defense Juwono Sudarsono, 2006)

change in the structure, not to mention the other changes in the existing command structures.

The existing structure puts the helicopter squadrons and the helicopter maintenance squadron under direct command of KOOPSAU I. On the other hand, the depot level maintenance unit (SATHAR 16) is under direct command of KOHARMATAU. To propose an order for a certain material or to report the inventory status, the units under those two major commands should submit the paperwork to their direct superior command, which in turn will send the material requested, if any, to the Air Force Headquarters (Helicopter Subdirectory) and keep the inventory status records in the data storage (usually paper-based). Since the lower units also send copies of the paperwork to the Helicopter Subdirectory, the common practice is for the lower unit to unofficially linked directly to the Headquarters. The reason is to avoid delays due to information system in the supply chain within the organization; thus, they bypass the structure.

With information technology, the information flow can reach the intended destination without any delay and the proper responses can be made immediately. Units can send their status report to higher command and at the same time, their report can also be read by the Helicopter Subdirectory. When the MRP system is implemented to manage the inventory, the KOOPSAU I and KOHARMATAU would become the center of input gathering for their respective subordinate units. Then in turn, the Helicopter Subdirectory processes the input into an inventory acquisition process in accordance with the DOD.

This research proposes the MRP system architecture which will link each element of helicopter maintenance units as well as the DOD to the suppliers (local or from foreign countries). The KOOPSAU I and KOHARMATAU act as the main input providers for the MRP system. The MRP will send the inventory status to the suppliers, but the key to execute the procurement processes is the DOD. Therefore, the role of the DOD in this structure is executing the material procurement. There would be some delay, however, in the procurement process due to the availability of funds. And that is the only delay since the other factors which usually create delay would have been neutralized by the use of the

information system in MRP. Figure 2 below illustrates the system architecture of the proposed inventory management for aircraft maintenance operations.

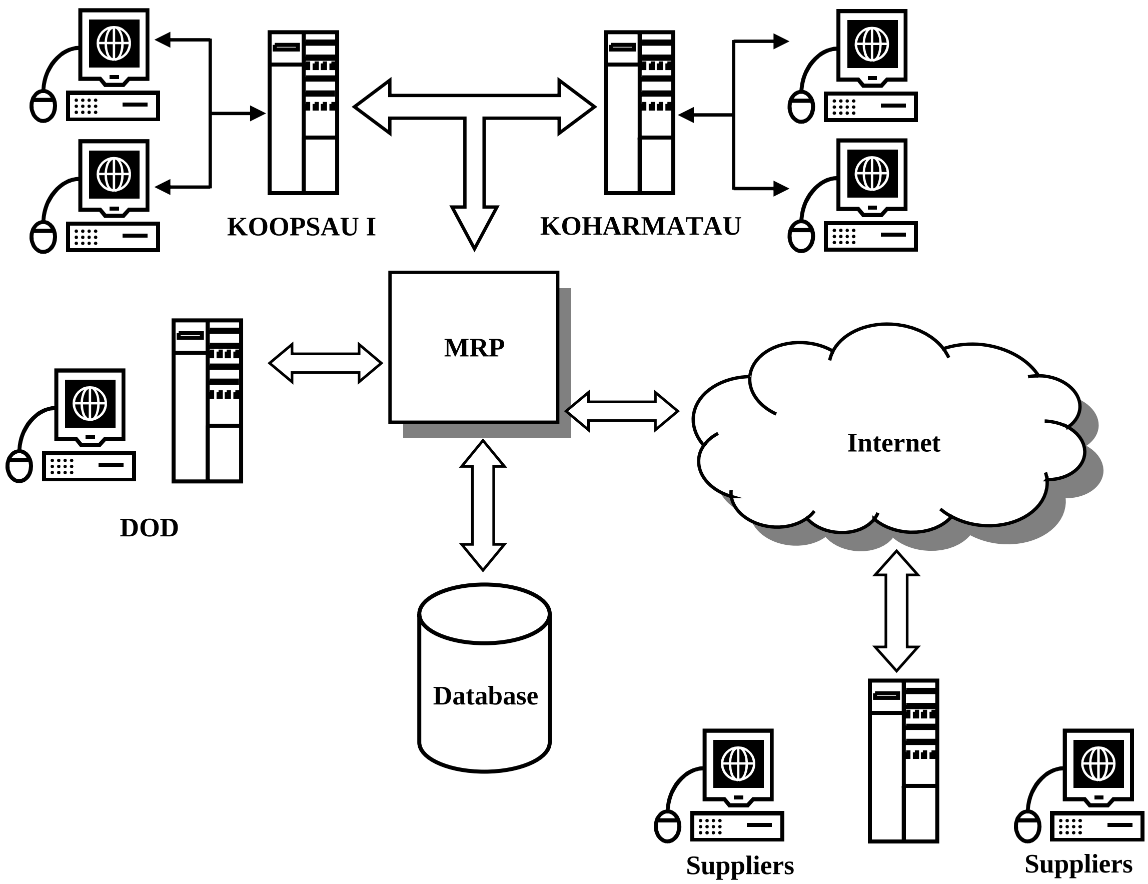

Figure 17. MRP System Architecture

The implementation of this architecture requires the creation of an IT section to control and operate as well as maintain the information technology used. Therefore, the IT section does not necessarily involve connection to the MRP processes.

On the other hand, this arrangement would create a degree of resistance from those whose current position is threatened by the BPR. As Tsai (2003) said, BPR connotes change and, since people are averse to change, there would be a degree of organizational resistance to reengineering processes. It appears in many different forms,

from stoicism to intentional sabotage because many people would feel afraid, alienated and uncertain about their future. Change also means more work to be done. For example, the creation of the IT section means new forms of organizational learning as well as developing new skills. And they must be done because the essence of reengineering is to recognize and to break away from the outdated rules and fundamental assumptions that underlie operations (Hammer, 1990).

E. CHAPTER SUMMARY

The legacy system currently employed by the Indonesian Air Force is outdated related to the emergence of advanced information technology. The old system and the old rules still have decisive effect in determining the material procurement processes. To improve inventory management, this research proposes the implementation of Material Requirement Planning supported by Business Process Reengineering.

The implementation of an MRP system to improve inventory management is intended to minimize the information deviation during the transfer. The system, if used properly, can provide the exact number of items required by the Air Force to maintain its helicopter fleet. It will minimize the risk of inaccurate information because of duplicated data or because the information is not conveyed in real-time. Moreover, the MRP system implementation might redefine the role of the higher commands in the supply chain by put them into key input elements.

This improvement in turn requires redesign or reengineering to commence the business. The Business Process Reengineering is intended to replace the old legacy system which is outdated with the new method which utilizes information technology to optimize business outcomes. The reengineering efforts, however, usually are resisted by the people in the organization. The resistance comes from the people who feel uncertain about the future after the redesign process in the business. The emergence of information technology and the need to add an IT section also might increase the resistance for the people who have little or even no skill in that field.

The biggest challenge, as Tsai (2003) explained, is to integrate the old system with the new web-based application. Tsai said that it is not only about "adapting to the

new technology, but also developing the new strategies to integrate the new technologies with enterprise application system."

THIS PAGE INTENTIONALLY LEFT BLANK

VI. CONCLUSIONS AND RECOMMENDATIONS

A. CONCLUSIONS

Material Requirement Planning (MRP) has been widely acknowledged as the method to improve the inventory management systems in doing business. The MRP system provides an alternative way for the Indonesian Air Force to manage its inventory to support the aircraft maintenance operations. It can not only shorten the material acquisition process by employing advanced information technology to convey the data along the supply chain, but also minimize the data deviation caused by inaccurate inventory status reports by various units.

To implement the MRP effectively, this research recognized the importance of Business Process Reengineering (BPR). BPR offers a radical way to redesign the business process. It will replace the outdated legacy systems in the Indonesian Air Force supply chain with the new one which can handle the business effectively and efficiently by utilizing information systems. Not surprisingly, BPR would also create a form of resistance during the process. The redesign process, however, can be perceived as the way to improve the supply chain.

To describe the result of the study and the advantage of it for the Indonesian Air Force, this thesis addresses each of the initial research questions.

1. How effective is the current information system?

How effective is the current information system used by the Indonesian Air Force in its aircraft maintenance management and how was it implemented? Chapters I and II revealed that the information system in the Indonesian Air Force still relies heavily on a paper-based reporting system supported by the telephone line network and facsimile machines. The role of computers which are widely used throughout the Air Force is limited to document formatting. They are not linked in a network system to support administrative tasks. For some of the US built aircraft, however, the Indonesian Air Force has already utilized the Automatic Logistic Management System (ALMS) to manage the spare parts inventory.

The ALMS links the Indonesian Air Force to the aircraft material suppliers in the United States. When the stock in the inventory decreases, the information is relayed to the supplier's database. The suppliers then prepare the material needed. An order can be made after the Air Force receives funds to purchase the material from the Department of Defense. This system, however, regardless of the fact that it uses advanced information technology to convey the material information, is not compatible with every aircraft type in the Indonesian Air Force fleet. ALMS is only useful for U.S. built aircraft and cannot be used for aircraft from other countries.

Moreover, even though the ALMS is embracing the information system concept, the spare parts for its hardware technology are not supported by the local market. In addition, the ALMS connection sometimes interfered with the political situation between the Indonesia and the United States. The inventory information is relayed to the suppliers in the U.S. but the procurement process is sometimes suspended by the U.S. government.

From this information, this thesis concludes that the information system in the Indonesian Air Force to support the material procurement for helicopter maintenance is not sufficient and needs to be improved.

2. How should inventory management be improved?

How should inventory management be improved in the Indonesian Air Force's aircraft maintenance operation and supported by the appropriate information system? The Indonesian Air Force is currently using the simple forecast method to "predict" the material requirement for helicopter maintenance operations. As explained in the Chapters II and V, this method is often inaccurate in determining the right amount of material for aircraft maintenance requirements as well as the right time to make materials orders. This is because of the legacy system in inventory management which relies heavily on a paper-based information system. To permeate an accurate material acquisition into procurement processes, the underlying information from the user should be sufficient and accurate.

To rectify the current inventory management situation, the Air Force has to redesign the information system along the supply chain, so that the information conveyed

to the higher command can be processed more accurately. More important, the improved information system may integrate the inventory status records from the warehouses with the maintenance operations planned by the helicopter squadrons and helicopter maintenance squadron as well as the SATHAR 16 at depot level maintenance. This will result in accurate inventory data and can help avoid unnecessary inventory record duplication.

3. How should the supply chain be improved?

How should the supply management in the aircraft maintenance process be improved in order to reduce time and unnecessary costs? In the era of information technology, the Indonesian Air Force can use the inventory management software which is based on information system technologies. The software can replace the legacy system in the helicopter inventory management for maintenance operations which is still based on the simple forecasting method. One type of inventory management software is Material Requirement Planning (MRP).

MRP system can provide more accurate calculation of the material requirements to maintain the helicopter fleet in the Indonesian Air Force. It conveys the information from the field units (helicopter squadrons, helicopter maintenance squadron and depot level maintenance unit) containing the number of items required and processes the information into useful data. This data in turn are processed and the output can determine the exact number of material items that must be ordered. This action can avoid unnecessary cost due to inaccurate orders and can also increase efficiency since the materials ordered are the right ones.

To implement the new inventory system method and replace the legacy system, the Air Force should redesign its business processes. The Business Process Reengineering (BPR) in the Air Force has two objectives. First, it will redefine the roles of the KOOPSAU I and KOHARMATAU in the MRP system to support inventory management in the helicopter maintenance operations. Second, it is intended to shorten the supply chain between the user and the suppliers. Consequently, the role of the intermediaries in providing materials for helicopter maintenance can be minimized. The

author believes that the BPR implementation will likely be met with some degree of resistance. Nevertheless, redesigning the business process is a must to improve current inventory management.

4. What might affect the implementation of the Information System?

What might affect the implementation of the information system in the aircraft maintenance operation and management? The author recognizes two factors that are affected by the implementation of an information system in the Indonesian Air Force. First, there would be a decrease in costs and processing time. Second, the implementation will affect the organizational structure.

With the implementation of an advanced information system based on web-based information technology, inventory management can be executed more quickly and in real-time. Moreover, the information pertaining to the material data is also more accurately conveyed throughout the supply chain. Chapters III and IV explained that the use of a web-based information system can shorten the business processes time; thus, increasing efficiency and effectiveness. With the increased efficiency, the unnecessary costs arising as a result of extra work can be significantly reduced. As a developing country with limited resources, cost reductions should be the first priority. The more cost reduction obtained from the procurement processes, the more optimum budget allocation can be obtained, and finally, the more materials can be purchased by using the same amount of money.

The implementation of the information system using web-based technology will also affect the organizational structure. The information system will require the formation of a group to handle the information technology. It also enables the elements within the supply chain to coordinate the effort to manage the business in a cross organizational boundary manner (Davenport and Short, 1993). Currently, the biggest challenge to implementation of a web-based information system is a lack of understanding of the concept of business process reengineering (BPR) with an information system in it to replace the legacy system in order to make improvements. This lack of understanding will lead to organizational resistance. Nevertheless, the

Indonesian Air Force cannot avoid the need to redesign its business processes in order to keep pace with the advanced technologies. Hammer (1990) says that "reengineering strives to break away from the old rules about how we organize and conduct business." Moreover, he says that "the reengineering process involves recognizing and rejecting some of the old rules and then finding imaginative new ways to accomplish work."

B. RECOMMENDATIONS

This thesis provides an overview of inventory management and business transformation components for the Indonesian Air Force to make improvements in providing materials required for helicopter maintenance operations. This thesis also provides a basic model for the implementation of an MRP system to improve inventory management in the Air Force.

The thesis' intent is to promulgate a better inventory management system which is already known widely to the Air Force so it can manage the helicopter fleet effectively; and make it a model for the other types of aircraft in the Air Force inventory. Moreover, this study urges the importance of having a reliable information system which is independent of a political relationship with any country so that the political situation would not interfere with the supply chain network.

Within the study of inventory management and business process reengineering in the Indonesian Air Force, there are several areas of studies for future research as follows:

- How, specifically, does the implementation of inventory management concepts assist the budgeting process in order to enhance the decision making in allocating the limited resources?
- How could business transformation in the Air Force be measured?
- How would the information technology as a core system, backed up by the paper-based administration works, be promulgated to enhance the business processes in the Air Force?
- How could the e-business concept in the Air Force business process be implemented regarding internet security issues?

- How would the implementation of Business Process Reengineering reach the financial management sectors so they can be included in the business transformation effort?

- How could the Material Requirement Planning method pave the way for the implementation of a more advance inventory management system such as Lean Six Sigma method in the Air Force as a model for the Indonesian Armed Forces?

LIST OF REFERENCES

Beer, Michael, and Nohria, Nitin, *Cracking the Code of Change, Harvard Business Review*, May-June 2000.

Boynton, Andrew C., Jacobs, Gerry C., Zmud, Robert W., Whose Responsibility Is IT Management? In *Business Process Reengineering: Current Issues and Applications*. In *Business Process Reengineering: Current Issues and Applications*, pp.85-90, Norcross: Industrial Engineering and Management Press, 1993.

Chase, Richard B., Aquilano, Nicholas J. and Jacob, F. Robert, "Operation Management for Competitive Advantage." In *Operations Management*, pp. 111-136, McGraw-Hill Custom Publishing, Inc., 2004.

Cook, Glenn R., and Dyer, Jefferson D., *Business Process Reengineering With Knowledge Value Added In Support Of The Department Of The Navy Chief Information Officer*, Master's Thesis, Naval Postgraduate School, 2003.

Davenport, Thomas H., Short, James E., Ernst and Young, "The New Industrial Engineering: Information Technology and Business Process Redesign." In *Business Process Reengineering: Current Issues and Applications*, pp.110-115, Norcross: Industrial Engineering and Management Press, 1993.

Duck, Jeanie Daniel, *Managing Change: The Art of Balancing*, Harvard Business Review, November-December 1993.

Grover, Varun, Teng, James T.C., and Fiedler, Kirk D., "Technological and Organizational Enablers of Business Process Reengineering." In *Business Process Change: Reengineering Concepts, Methods and Technologies*, eds. Varun Grover and William J. Kettinger, pp 16-31, London: Idea Group Publishing, 1998.

Hammer, Michael, Reengineering Work: Don't Automate, Obliterate. In *Business Process Reengineering: Current Issues and Applications*, pp.25-35, Norcross: Industrial Engineering and Management Press, 1993.

Harrison, Terry P., "Principles For The Strategic Design of Supply Chain." In *The Practice of Supply Chain Management*, ed. Harrison, Terry P., Lee, Hau L. and Neale, John J., pp.4-11, Boston: Kluwer Academic Publishing, 2003.

Hutchins, David, "Just In Time", 2nd ed. Hampshire: Gower, 1999.

Koch, Christopher, "The ABCs of ERP", CIO, accessed January 2006; available from http://www.cio.com/research/erp/edit/erpbasics.html

Kotter, John P., *Leading Change: Why Transformation Efforts Fail, Harvard Business Review*, March-April 1995.

Neale, John J., Tomlin, Brian T. and Willems, Sean P., “The Role of Inventory in Superior Supply Chain Performance.” In *The Practice of Supply Chain Management*, ed. Harrison, Terry P., Lee, Hau L. and Neale, John J., pp.31-57, Boston: Kluwer Academic Publishing, 2003.

Norris, Grant, Hurley, James R., Hartley, Kenneth M., Dunleavy, John R., Balls, John D., *E-Business and ERP: Transforming the Enterprise*. New York: John Wiley & Sons, Inc., 2000.

Orickly, Joseph, “Material Requirement Planning”, New York: McGraw-Hill Book Company, 1975.

O’Brien, Timothy J., *Suitability Of MRP II To Material Planning For Component Repair At Naval Aviation Depot, North Island*, Master’s Thesis, Naval Postgraduate School, 1998.

Piasecki, Dave., "Optimizing Economic Order Quantity." *IIE Solutions*, January 2001, pp.30–39, accessed December 12, 2005; available from http://www.iienet.org/membersonly/backissues/101piasecki.pdf; Internet.

Porter, Michael E., *Strategy and the Internet*, Harvard Business Review, March 2001.

Porter, Michael E., and Rivkin, Jan W., *Industry Transformation*, Harvard Business School, June 2000.

Sethi, Suresh P., Yan, Houmin and Zhang, Hanqin, *Inventory and Supply Chain Management with Forecast Updates*, New York: Springer, 2005.

Simchi-Levi, D., Kaminsky, P. and Simchi-Levi, E., “Designing and Managing the Supply Chain: Concepts, Strategies and Case Studies.” In *Operations Management*, pp. 185-197, McGraw-Hill Custom Publishing, Inc., 2004.

Simchi-Levi, D., Simchi-Levi, E. and Watson, Michael, “Tactical Planning For Reinventing The Supply Chain.” In *The Practice of Supply Chain Management*, eds. Harrison, Terry P., Lee, Hau L. and Neale, John J., pp.14-30, Boston: Kluwer Academic Publishing, 2003.

Thoben, Klaus-Dieter, Eschenbächer, Jens and Jagdev, Harinder S., “Emerging Concepts in E-Business and Extended Products.” In *E-Business Applications: Technologies for Tomorrow’s Solutions*, eds. Jorge Gasós and Klaus-Dieter Thoben, pp.18-36, Berlin: Springer, 2003.

Tsai, Hui-Liang, *Information Technology and Business Process Reengineering: New Perspectives and Strategies*, London: Praeger Publishers, 2003 Davenport, Thomas H., Business Process Reengineering: Where It’s Been, Where It’s Going. In *Business Process Change: Reengineering Concepts, Methods and Technologies*, ed. Varun Grover and William J. Kettinger, pp 1-11, London: Idea Group Publishing, 1998.

Wight, Oliver W., “Production and Inventory Management in the Computer Age”, Cahners Books International, Inc., 1974.

Wild, Tony, “Best Practice in Inventory Management”, New York: John Wiley & Sons, Inc., 1997.

THIS PAGE INTENTIONALLY LEFT BLANK

INITIAL DISTRIBUTION LIST

1. Defense Technical Information Center
   Ft. Belvoir, Virginia

2. Dudley Knox Library
   Naval Postgraduate School
   Monterey, California

3. Professor Glenn R. Cook
   Naval Postgraduate School
   Monterey, California

4. Professor Uday M. Apte
   Naval Postgraduate School
   Monterey, California

5. Captain Martinus Bram Susanto
   Atang Sendjaja Air Force Base
   Bogor 16310
   Indonesia